



**ANALYSIS OF FLOOD RESILIENCE USING PARTICIPATORY GIS APPROACH
MONITORING FLOOD AND INTERVENTIONS
CASE STUDY OF SEBEYA CATCHMENT**

By

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**College of Science and Technology
School of Architecture and Built Environment**

**Master's degree of Geo-information Science for Environment and Sustainable
Development**

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**A dissertation submitted in partial fulfilment of the requirement for the degree of
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DECLARATION

I declare that this dissertation contains my own work and has not been submitted for any other degree at University of Rwanda or any institution.

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Signed:

Date: 18/08/20

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ABSTRACT

Flooding is becoming more and more a big problem in the world that needs to be looked at seriously. Flood cannot be stopped, but effort can be made to start thinking about how to live with floods. The main objective of this study is to assess the flood resilience techniques put in place by the community and stakeholders in Sebeya catchment. The research is based on a participatory approach to assess the resilience techniques in place using Remote sensing and GIS technologies to respectively identify exposure in the flood prone area, and map existing resilience. The Sebeya flood prone area developed by the Ministry of Disaster and Refugees through the Disaster Risk Atlas of Rwanda was used to identify area of study. A high spatial resolution drone imagery superposed to the flood prone area was used to identify household exposure to flood. ArcGIS software was used for image analysis, field data collection, data analysis, visualisation and Flood Resilience Digital Interactive Map (FRDIM) development. Focus Group Discussion was conducted to assess existing resilience techniques and map proposed resilience strategies. A survey was done for all the households within identified clusters flood prone. The findings show that in total 801 constructions were found exposed to flood with 93.7% highly exposed to flood. In terms of resilience, 74% of exposed houses have a resilience technique in place. The resilience techniques that are popular are sand bags and trees plantation. The existing resilience techniques are perceived to be non-efficient methods by the population. Main proposed strategies are creation of artificial lake and deviation of Sebeya. An integrated web application was developed to harness flood resilience real time reporting ; flood resilience projects and techniques assessment and also as a tool for community participation in donating their land for more open space along the river. In conclusion a sustainable flood resilience in Sebeya requires the developemnt of engineering flood resilience methods for better risk reduction and the use of integrated web application for better report and evaluation of flood techniques implemented by the stakeholders and the community.

Key words: Flood Resilience, Participatory GIS, Digital Interactive map

LIST OF SYMBOLS AND ACRONYMS

AL:	Artificial Lake
ACP-EU:	African, Caribbean and Pacific Group of States – European Union
CoEB:	Center of Excellence for Biodiversity and Natural Resources Conservation
CORFU:	Collaborative Research on Flood Resilience in Urban Areas
DEM:	Digital Elevation Map
DRR:	Disaster Risk Reduction
GEF:	Global Environmental Facility
GFT:	GIS Flood Tool
ESRI:	Environmental System Research Institute
FEMA:	Federal Emergency Management Agency
FRDIM:	Flood Resilience Interactive Map
FRMC:	Flood resilience measurement for communities
FGD:	Focus Group Discussion
FONERWA:	National Fund for Environment in Rwanda
GIS:	Geographic Information System
IFRC:	International Federation of Red Cross and Red Crescent
IM:	Interactive Map
IUCN:	International Union of Conservation and Nature
LAFREC:	Landscape and Forest Restoration for Environmental Conservation Project
MINEMA:	Ministry of Emergency Management
MIDIMAR:	Ministry of Disaster Management Affairs and Refugees
P-GIS:	Participatory GIS
RCMRD:	Regional Center for Mapping of Resources for Development
REMA:	Rwanda Environmental Management Authority
RMA:	Rwanda Meteorology Agency
RLMUA:	Rwanda Land Management and Use Authority
RWFA:	Rwanda Water and Forestry Authority
UNDRR:	United Nations for Disaster Risk Reduction
UNISDR:	United Nations for International Strategy for Disaster Reduction
UNEP:	United Nations for Environment Protection
UR:	University of Rwanda
UPI:	Unique Parcel Identifier

TABLE OF CONTENTS

DECLARATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT.....	v
LIST OF SYMBOLS AND ACRONYMS	vi
LIST OF TABLES.....	ix
LIST OF FIGURES.....	x
CHAPTER I: INTRODUCTION	11
1.1. Background Information.....	11
1.2. Problem Statement.....	13
1.3. Objective of the study.....	13
1.3.1. Main objective.....	13
1.3.2. Specific objectives	13
1.4. Research questions	14
1.5. Significance of the research	15
1.6. Organization of the report.....	15
CHAPTER II. LITTERATURE REVIEW	16
2.1. Flood Resilience.....	16
2.2.1. Zurich Resilience Framework.....	18
2.2.2. The 5R Flood Resilience Framework	19
2.2. Flood resilience strategies	19
2.2.1. Use of sand bags.....	20
2.2.2. Trees plantation	20
2.2.3. Dikes and flood retaining walls.....	20
2.2.4. Drainage systems	21
2.2.5. Man-made reservoirs or Artificial Lake (AL).....	21
2.2.6. River Deviation	21
2.2.7. Relocation and Zoning	22
2.3. Community level Involvement and Participatory GIS (P-GIS).....	22
2.4. Flood resilience Interactive Map	23
2.5. Sebeya flood resilience stakeholder Analysis.....	23
2.6. Theoretical Conceptual framework	25
2.7. Summary of the chapter	26
CHAPTER III. RESEARCH METHODOLOGY	27
3.1. Description of Study Area.....	27
3.2. Data collection	28
3.2.1. Secondary data collection	29

3.2.2. Primary data collection.....	29
3.2.2.1. Interview with key informants	30
3.2.3. Image processing	34
3.4. Data processing.....	35
CHAPTER IV. RESEARCH RESULTS AND DISCUSSION.....	36
4.1. Building Exposure to Flood	36
4.1.1. Number of buildings in the three villages.....	36
4.1.2. Houses that experienced floods in clusters	36
4.1.3. Buildings' exposure to flood	37
4.1.4. Period of the settlement in the area	38
4.2. Flood Resilience techniques in place.....	39
4.2.1. Proportion of protected buildings.....	40
4.2.2. Type of resilience techniques in place.....	40
4.2.3. Stakeholders' contributions in mitigating flood	42
4.3 Proposed strategies for better flood resilience	43
4.3.1. Creation of artificial lakes around tea plantation	43
4.3.2. Deviation of Sebeya	44
4.3.3. Removing all Sebeya's meanders	45
4.3.4. Construction of underground pipes.....	45
4.3.5. Leveling off Karambo mound	45
4.4. Research discussion.....	46
4.5. Conclusion of the chapter	47
CHAPTER V. FLOOD RESILIENCE DIGITAL INTERACTIVE MAP (FRDIM)	48
5.1. FRDIM Inputs	48
5.2. FRDIM Output.....	49
5.3. Relevance of the Application.....	53
5.4. Use of the Application.....	53
CHAPTER VI: CONCLUSION AND RECOMMENDATIONS.....	54
6.1. Conclusion and Recommendations	54
6.2. Room for Further Research	55
References	56
Appendices.....	61
Appendice 1. Survey Questionnaire.....	62
Appendice 2. Propose solution Survey questionnaire Survey form	65
Appendice 3. Flood event and Resilience Report Survey form	66

LIST OF TABLES

Table 1: Compatibility research matrix 14

Table 2: Flood risk equation 17

Table 3: Stakeholder Matrix 25

Table 4: Sources of spatial data used..... 29

Table 5: Flood exposure indicator 35

Table 6: Population awareness on stakeholders involved in flood resilience 42

LIST OF FIGURES

Figure 1: Zurich flood resilience framework.....	18
Figure 2: 5R flood resilience framework.....	19
Figure 3: Flood Resilience Assessment Conceptual Framework	26
Figure 4: Study Area Map	28
Figure 5: Location of clusters	31
Figure 6: Focus group discussion sessions.....	33
Figure 7: Parcel identification and extraction.....	34
Figure 8: Exposed constructions/footprint and their corresponding land parcels	36
Figure 9: Number of households which have experienced flood	37
Figure 10: Number of houses (%) per level of exposure.....	38
Figure 11: Exposure of houses	38
Figure 12: Distribution of respondents (%) per length of stay in the area prone to flood.....	39
Figure 13: Existing flood resilience techniques	40
Figure 14: Techniques for flood resilience	41
Figure 15: Structural techniques for flood resilience	41
Figure 16: Proposed resilience techniques proposed by participants during FGD.....	44
Figure 17: Digital Interactive Map System	48
Figure 18: Sebeya land use by parcel with UPI number	51
Figure 19: Open space preservation credit request tool	52
Figure 20: Sebeya Flood Resilience Strategies Digital Map.....	52
Figure 21: Proposed resilience Form.....	65
Figure 22: Overview of the form.....	66
Figure 23: Flood event report	67
Figure 24: Damage report form	68
Figure 25: Resilience problem report form	69

CHAPTER I: INTRODUCTION

1.1. Background Information

Nowadays floods can be as alarming as wars are. Among all the disasters, flood is one of the most damaging and the most occurring disaster where almost 44% of death caused by disasters are attributed to flood and in the 1,658 economic damages flood itself count 41,7% (IFRC, 2018). Only in two days, the flood of August 5, 2011 in Thailand which was by far the most economically damaging flood between 1900 and 2013 caused roughly 40 billion U.S. dollars of damage and killed 42 people (World Statistics, 2017). The extreme floods in Western Rwanda led to the death of dozens of people, destroyed roads and other infrastructures, left many people homeless and created food insecurity in the province (MIDIMAR, 2012). Early September 2018 floods took life of almost 5,000 people in Nigeria (Davies, 2018). The same year, Rwanda lost 18 people, over 4,500 hectares of crops have been destroyed and 705 livestock killed since January (Floodlist, 2018).

Rwanda is one of the flooded areas in Africa due to its steep slope (IFRC, 2015). With the phenomenon of climate change, flood has put into trouble some districts like the district of Rubavu where in 2017 sectors of Rugerero, Kanama and Nyundo were highly affected by flood with 25,000 people affected and 28 houses completely destroyed (IFRC, 2017). In Rwanda flood changed a lot of people life, people were deprived of their daily life and culture, where only from January to April 2018 in Gasabo, Rulindo, Gatsibo and Rubavu districts 50,000 people were displaced, 116 death and 200 injuries, 1201 houses and 33 bridges were destroyed due to flood (Floodlist, 2018). In December 2019 on Christmas night the city of Kigali was punched by a heavy rain which flooded the city, according to the Floodlist (2019), 12 people died, 113 houses were destroyed, and the rain affected the supply of water within the city.

Moreover, flood risk around Gishwati and Mukura landscape is mostly due to a significant loss of forest (MINILAF, 2017), rainfall beyond the carrying capacity of Sebeya river, illegal mining activities along that river which cause obstruction of free-flow of river and expansion of settlements in the flood prone areas (Yambabariye & Hishamunda, 2018). Flood is also caused by lack of information on mitigation measures, settling in high risk areas such as mountain slopes, culture belief, informal nature of houses and low level of preparedness. The most

vulnerable districts due to its topography, population pressure and soil are Nyabihu, Rubavu, Musanze, Burera and Gakenke (MIDIMAR, 2016).

However, in Rwanda as stated by the Director of Disaster Risks Reduction at the Ministry of Emergency Management (MINEMA), in his interview on Sendai Framework (UNDRR, 2018), “Disaster risk reduction has been integrated within key development sectors such as infrastructure, agriculture, environment, education, urbanization, information, communications, technology and youth”. Individuals, households and communities have come up with some coping strategies like relocation to safer areas, trees planting trees, terracing and receipt of aid and relief (Osuret et al, 2018). Different projects are working in the flood prone areas in districts flood prone and different resilience methods are being put in place. The project Landscape Approach to Forest Restoration and Conservation (LAFREC) has put into place the strategies to reduce flood risk within the community where \$500,000 are allocated for flood risk management activities (World Bank, 2017) in the North-west of Rwanda, especially in regions surrounding Mukura-Gishwati national park. A flood management plan for Sebeya catchment has been put into place by Water for Growth in collaboration with Rwanda Water and Forestry Authority (RWFA) and International Union of Conservation and Nature (IUCN) as a strategy to increase people resilience to flood (IWRM, 2018).

Today, international organisations are investing millions in flood resilience within Sebeya flood area, but there are still challenges to evaluate the strategies put in place and impact on the community. Thus, there is no mean to evaluate the impacts and highlight gaps between investment in terms of financial support and the reduction of flood risk in Sebeya catchment. From the year 2015 in total, it is estimated that more than 30 billion Rwf was spent to put in place resilience strategies. The major contributors are the Dutch Government which allocated Rwf 22 billion for flood risk reduction in Sebeya catchment, Rwf 15 billion out of this amount was dedicated for flood resilience in 2015(IWRM, 2018). This rises up our need to build an updatable real time flood resilience evaluation and future investment tool which will led and bring statistics on what is working depending on the reduction of damages within areas where the coping capacities have been applied.

1.2. Problem Statement

Different measures and strategies have already been taken by different authorities to reduce flood risks in Rwanda. The most common flood mitigation measure due to lack of alternative preparedness mechanisms, has been the relocation of people and activities from flood prone area (MIDIMAR, 2015). However there have been cases of people acting violently when stopped from building houses in such dangerous places, an act of irresponsibility, disobedience other complained that they have not been involved into decision making (RNP, 2015). There is a complete lack of understanding, from the decision-making point of view, of why people resist the relocation to safer locations. It is against this background that this study was undertaken in Sebeya catchment where huge amount of Rwf have been invested in order to reduce flood risks but still the catchment faces recurrent floods and associated damages. The study will focus on the region around Mahoko Centre where flooding is very recurrent.

The study aims at assessing the problem of flooding, local perceptions and priorities for understanding adaptation and peoples' coping strategies on flood. It is worth noting that with the ongoing climate change and the ever-increasing populations of Rwanda, the current response to relocate people and services will become increasingly challenging. Therefore, it is crucial to find sustainable and environmentally friendly methods that can help people and their surroundings to adjust to flood willingly, 'it is time to know how to live with flood as we must live with climate change'

1.3. Objective of the study.

1.3.1. Main objective

The current research aims at assessing flood resilience's techniques put in place in Sebeya catchment by different stakeholders and the community and at developing a tool for real time reporting of encountered problems and improvement needed.

1.3.2. Specific objectives

To attain the above general objectives, this study will specifically

1. Identify exposed households within Sebeya flood prone area,
2. Identify and map existing flood resilience techniques, and
3. Propose flood resilience evaluation tool which will be helpful for future resilience implementation strategies.

1.4. Research questions

The study addressed the following specific questions:

Table 1 presents the research questions and summary of methods to be used to achieve the objective set. It also presents associated specific objectives. The output represents the representation or format to measure if the specified objective it has been achieved or not.

Table 1 : Compatibility research matrix

Specific objective	Research question	Methods	Output
Identify exposed household within Sebeya flood prone area	– How many Households are exposed to flood? – What are households at extremely risk to be affected by floods?	Digital extraction of building on 2019 drone imageries	Flood Exposure Map
Identify and map existing flood resilience techniques	– What are the techniques put in place by the community and stakeholders to reduce flood risk? – What should be the best strategy to control flood risks?	-P-GIS -Analysis report from different stakeholders Focus Group discussion Survey Questionnaire	– Maps, tables and graphs of existing resilience methods – Proposed Strategies Map
Propose Flood resilience evaluation tool which will be helpful for future resilience implementation strategies	– What are existing, planned and proposed resilience strategies within Sebeya Catchment? – Where should be the next investment to reduce flooding – What is the strategy to report in real time on flood resilience?	ArcGIS Tools for Configurable Digital and dynamics Maps	Interactive and Dynamic Maps

1.5. Significance of the research

Evaluation of strategies in place is one way to go to a sustainable flood mitigation measure. Experiences could teach one on best practices, thus guide new decision making. Flood cannot be stopped but there are possibilities to live with flood without being affected negatively. This study will help for future and sustainable investment to reduce flood damages. There is no way to escape to this phenomenon of climate change risks if it is not best planning and critical spirit. A flood resilience platform could help in the transparency and efficiency of reducing flood and impact sustainable investment.

1.6. Organization of the report

This thesis is organized in six main chapters. The first chapter gives an introduction and background of our study. The second Chapter (Chapter II) describes research framework, definitions and existing research theories on the topic. Chapter III represents description of our study area and identification of clusters, the chapter also describes the methods used to identify exposure and flood resilience in the area. Chapter IV represents the results and discussion; an additional chapter (Chapter V) was added to elaborate the process of the development of the Flood Resilience Digital Interactive Map (FRDIM). Then Chapter VI summarizes the major findings and formulates recommendations and possible future research.

CHAPTER II. LITTERATURE REVIEW

This chapter is based on existing literature on flood resilience strategies. Flood hazard have been into discussion during years and years. A lot of researches have been done on flood vulnerability and flood hazard but there is a lack of research about flood resilience which led to lack of theoretical flood resilience frameworks for better flood risk management. In Rwanda studies about flood have been flowing this last decade. Different authors (Bizimana & Schilling, 2010; Tsinda, 2009; Habonimana et al., 2018; Mugisha, 2015, etc.) have discussed and developed flood prone area with the use of different technologies. However, these studies have focused on the flood hazard and flood vulnerability and most of the study have revealed the use of technology in assessing and delineating flood in Kigali City, no one focused on resilience. The aim of this chapter is to review existing flood resilience methods and assessment strategies around the world. The chapter will define key existing flood resilience terms for a better understanding. This chapter will also give a picture of flood resilience strategies and stakeholders in Sebeya catchment.

2.1. Flood Resilience

According to Walters (2015) “Resilience is the ability of systems to withstand or adapt to changes without being harmed in their functionality”. That definition somehow shows the versatility of the concept since resilience consists of both withstanding and adaptation. The objective of implementing resilience is the continuation of a system’s functioning by minimizing the consequences of a disturbance (Serre & Barocca, 2013). However, when talking about risk and vulnerability, resilience can be an important part of risk reduction. Therefore, we could not talk about flood risks if there is no exposure and yet we cannot talk about people being vulnerable if they have already put in place resilience methods. According to UNISDR terminology (2009) exposure is simply defined as people, property, systems, or other elements present in hazard zones that are thereby subject to potential losses whereas vulnerability is defined as the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. In his study (Aggarwal, 2015) illustrated the concept of the relationship between flood, exposure, vulnerability and resilience: where buildings are located on a flood plain, both hazard and exposure are present in the event of flood; where the piece of land in flood plain contains no buildings, the hazard is present, but exposure is absent, so there is no risk. This being, where efficient resilience strategies are put in place,

vulnerability and exposure do not count, so no risk. Table 2 compares the two different ways of conceptualizing flood risk (Kron, 2003). The first column represents the known flood risk equation which is based on three indicators and the second is based on the resilience theory definition developed above

Table 2: Flood risk equation

Flood Risk Equation with three indicators	Flood Risk Equation with three indicators
Risk = Hazard * Exposure * Vulnerability	Risk = (Hazard * Exposure * Vulnerability) – Resilience
Scenario: If hazard = 10; Exposure=10; Vulnerability= 15; Resilience=100 (Structure Methods Only) Scenario2: If Hazard= 20; Exposure= 10; Vulnerability= 15; Resilience= 250	
Scen1. Risk = 5 * 10 * 5 Risk = 250 Scen2. Risk = 5*10*15 Risk=1500	Scen1. Risk = (5 * 10 * 5) -100 Risk = 150 Scen2. Risk = (10 * 10 * 15) -2000 Risk = 0
In both cases the risk is low when the resilience is concerned, in the first scenario resilience can be defined as used of non-structural methods only which led flood to put the population at risk whereas in the 2 nd scenario the higher resilience can be explained by the use of both structural and non-structure measure which can reinforce the community resistance capability and then put the risk to zero.	

Sources: Kron, 2003, Lavell & Oppenheimer, 2018

Managing flood risks is a vast topic which is most of the time reduced to mitigation measures or as a management of floods after the occurrence. However, floods mitigation only is not enough and a shift towards a more integrated flood risk management, containing both structural and non-structural measures to prevent, defend, mitigate, prepare, respond and recover from floods events needs to be included in flood management plans (Raadgever et al., 2014). The non-structural measures include measures that reduce the damage of a flood event in case of exceeding of the flood prevention structures. These include measures like warning systems, emergency, spatial planning, floods-proofing buildings and insurance solutions (Merz, Hall & Disse, 2010). Whereas the structure measures are any physical construction to reduce or avoid possible impacts of hazards, or the application of engineering techniques or technology to achieve hazard

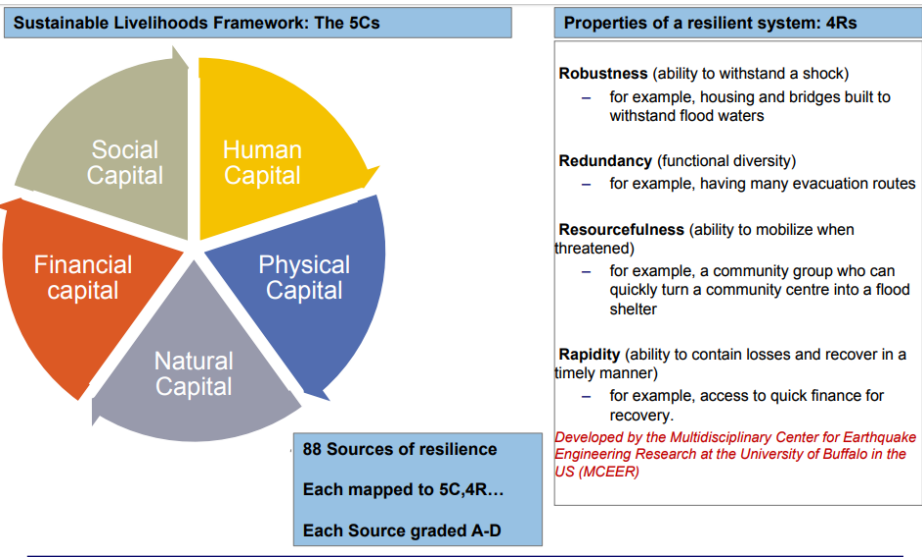
resistance and resilience in structures or systems, this can include dams, flood levies, flood walls, evacuation shelters (UNDRR, 2020).

2.2. Flood Resilience Framework

Measuring resilience is critical to demonstrate the impact of resilience enhancing initiatives. However few measurement frameworks exist and hardly any have been validated in the field according to the UNDP ‘no measurement framework for disaster resilience has been empirically verified yet’”(Zurich Group, 2017). Flood management companies have proven the interest to develop frameworks in the field by developing different flood resilience frameworks in regard to support their clients. Some have become popular like the Zurich Alliance flood resilience framework which helps their clients to understand their risks and prioritize improvements.

2.2.1. Zurich Resilience Framework

The Zurich Framework is one of the known frameworks about the flood resilience. The main objective of the development of the FRMC is to demonstrate impact on the ground and addressing the measurement gap by providing a consistent process and contributing to the evidence of what is resilience. This framework defines flood resilience as a whole system from resistance to recovery. The framework defines the resilience as the ability of a community to pursue its development and growth objectives, while managing its disaster risk over time in a mutually reinforcing way. The framework is based on system of digital data collection and a measurement model for assessing flood resilience within the community (Zurich, 2019).

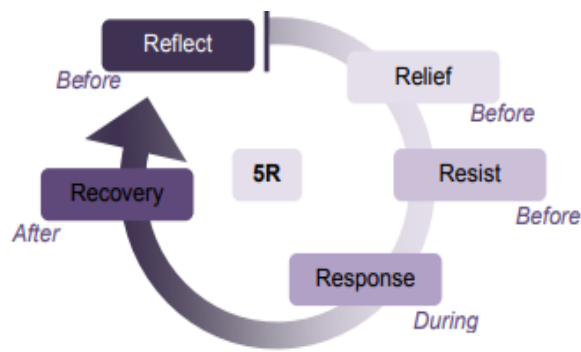


source: (Szönyi, Michael, 2017)

Figure 1: Zurich flood resilience framework

2.2.2. The 5R Flood Resilience Framework

This framework has been developed by the CORFU project. The framework integrates flood risk management through a framework that is employing five dimensions to evaluate the level of disturbance and ability to preserve and function during and after the flooding on one side and connected with the flood risk management cycle on the other side.



Source: Gourbesville & Batca, 2015

Relief – A buffer element. Implementation of physical, technical, non-structural and procedural measures relates to the concept “living with floods”, such as wet flood proofing.

Resist – Prevention of flood risk if possible, limiting floods damage and easing recovery by planning and adaptation

Response – Measures taken during the floods. Actions focus on crisis management coping capacity.

Recovery – Providing support to recovery processes and engaging and building capacity in communities enable to cope with the impacts after flooding events.

Reflect – Actions focus on increasing awareness and adaptive capacity, learning from past event and/or preparation for an uncertain future.

Figure 2:5R flood resilience framework

CORFU project which is a flood management project looks at improving the resilience strategies in different cities of Europe and Asia. The general flood management framework clarified the resilience of the system which is the before, during and after the event (Slobodan, 2011). CORFU has integrated different systems for better flood management. The full system includes a Real-time systems classification; Probabilistic forecast; Multi-layered models; Web-based flood forecast (DHI, 2013)

Both frameworks Zurich and CORFU consider resilience as a full flood management system. They considered resilience as the before, during and after flood event. The FRMC is more focused on creating a system to evaluate resilience of the community using the 4Rs properties of a resilient system from the Zurich framework by involving the community at a large scale with on ground reporting systems.

2.2. Flood resilience strategies

There is a bunch of strategies to cope with flooding worldwide. The list of techniques is not exhaustive since countries and institutions create and innovate in the area. No barriers or

standards are made of what should be done. Flood resilience techniques can go from natural management systems like sand bags, tree plantation, natural drainage system, waste water cleaning, to infrastructure protection systems like: floodwall, dikes, construction of ponds. In this study 8 resilience's techniques mostly known and used will be defined.

2.2.1. Use of sand bags

Traditionally, sandbags have been used for a long time as an easy way to block water to enter agriculture land, and building. Sand bags, is a technique made of bag and sand which is cheap and easy to obtain. Sand bags are recognized not being sustainable, however, as said by Padgham, et al. (2014), a well sandbagging planning tool can make sand bags technique efficient to reduce flood damages. This needs an easy way to fill bags with sands, define structured points of delivery of sand bag and strategy to report saved or lost sandbagged homes or buildings. However, sand bags are not always recommended as strong techniques to reduce flood risks, the government of United Kingdom strongly encourages people to use purpose made flood protection products, such as flood boards, non-return valves for plumbing and air brick covers (Environment Agency, 2009).

2.2.2. Trees plantation

Trees plantation is a natural flood management system which is used worldwide. Planting trees can be effective in increasing water infiltration and reducing and slowing runoff on farmland. Targeted tree planting in the upper catchment can lead to reductions in peak flows of up to 40 per cent (Woodland, 2014). When combined with other strategies, trees planted in the right places can do much to help with flooding before it happens. Afforestation as a method of flood resilience has been popular in a lot of countries. Calder and Aylward (2006) consider the solution in some countries as wastage of flood development funds since forests are not key or direct solution for flood mitigation measures.

2.2.3. Dikes and flood retaining walls

In other word called flood structural barriers or flood protection infrastructure, they are considered as strong methods to reduce flood risks with expensive technology and high maintenance cost. Once the infrastructure is well installed water cannot enter the protected area therefore it will not cause damages.

2.2.4. Drainage systems

The drainage system is needed to remove surface water. The drainage systems comprise different techniques like permeable surfaces, filter strips, infiltration devices, basin and ponds (Szollosi-Nagy, 2005).

2.2.5. Man-made reservoirs or Artificial Lake (AL)

In contrast to natural processes of lake formation, reservoirs are artificial, usually formed by constructing a dam across a river or by diverting a part of the river flow and storing the water in a reservoir. Upon completion of the dam, the river pools behind the dam and fills the artificially created basin (UNEP, 2000). Artificial lakes (AL) are recognized for their ability to reduce the peak discharge on downstream river. Not only artificial lakes can bring beauty but also, they can bring various activities and benefits to the community such as:

- Quick and easy access to water resource,
- Creation of drinking water and water for other uses,
- Increased protection of downstream river from flooding events,
- Increased potential for sustained agricultural irrigation,
- Production of energy (hydropower),
- Storage of water for use during low-flow periods and
- Increased fishery possibilities.

In his study, Samra (2017) remarks that even if AL are a simple way and efficient way of flood management, in practice to make the method efficient, there is a need to consider different technical matters like topography, soil condition, for avoiding the pond to be completely filled and cause inundation around. However, AL are more realistic under more frequent floods events because they cause higher peak reduction when the experienced flood is of low intensity.

2.2.6. River Deviation

Diversion channels or floodways are man-made channels built to offer a different route for excess water to flow further mitigating the effects of flooding and restoring rivers to their natural water level, they are built around communities or economic centers to prevent extensive flood damage (Alberta, 2013). The diversion of a river can be a very expensive technique and have unpredictable consequences to the environment if not well studied, however it can also bring

very strong and sustainable strategy for flood resilience if well studied. One of the important case studies is the red river floodway of Manitoba in Canada. The diversion of that river has been put in place by the city to protect Winnipeg from several potentially devastating floods. In 2000, the solution has been designated as a national historic site of Canada because it is an outstanding engineering achievement in function and impact of the engineered flood control system in the development of a major Canadian city (Park Canada, 2010).

2.2.7. Relocation and Zoning

Relocation is a flood management measure which is used as mitigation measure to clear or move to a new house from the flood pathway (Society, 2019). Moving people from the flood prone area is the most efficient methods however this method is not always the easiest. Relocation implies a lot of things; different studies have shown that relocation is frequently accompanied with several risks which are interlinked like: landlessness, homelessness, joblessness, loss of access to common property resources, marginalisation, food insecurity, morbidity and mortality, social disarticulation and uncertainty (Cernea, 1997).

2.3. Community level Involvement and Participatory GIS (P-GIS)

In the Hyogo framework for action the community has been given the top priority in disaster reduction. Disaster risk reduction must be located where people are hurting (UNISDR, 2013). With time, people gain a lot of experience with disasters by finding their own solutions and alternatives for them to stay alive and stay in the area. There is no doubt that the community should be in the center of all the process from planning to implementation

Participatory mapping or Participatory GIS (P-GIS) is a group of techniques for developing geospatial perceptions of landscapes (Kundu & Kundu, 2011). P-GIS for Disaster Risk Management is often mentioned in the literature as one of a standard example of P-GIS applications. P-GIS tries to empower marginalized groups and population with GIS technologies in the context of public involvement in community-based decision making (Sieber, 2006). P-GIS will help to identify existing resilience strategies and their implementer within our study area by using mapping technologies both paper maps and digital maps and forms. Application of P-GIS is effective where local people can accumulate knowledge and experiences like for floods events in the present case. Population in flood prone area, are the one affected so they are the one in the right place to give the right information.

2.4. Flood resilience Interactive Map

Interactive Maps are defined as intelligent maps that are responsive. Compared to static maps or paper maps, Interactive Mapping involves using maps that allow zooming in and out, panning around, identifying specific features, querying underlying data such as by topic or a specific indicator (e.g., socioeconomic status), generating reports and other means of using or visualizing select information in the map (Macfarlan, 2018). In his study about interactive maps (Roth, 2015) define Interactive map or Cartographic interaction as the dialog between a human and map, mediated through a computing device, and is essential to the research into interactive cartography, geovisualization, and geovisual analytics.

In Moreri's study (2008), the flood WebGIS or Interactive map was developed to assist flood warning practitioners as well as individual people to query information, for flood evacuation routes and to have an idea of the water levels on flooded roads. This era of technology allows things which were not possible before. Enhancing participation of the population can be done in a continuous way either by improving transparency, mobilize them and let them contribute in reporting and decision making.

2.5. Sebeya flood resilience stakeholder Analysis

Implementing resilience strategies implies involving multiple stakeholders and good collaboration between stakeholders is the key to success. The Government of Rwanda and different stakeholders have invested much money in flood mitigation and resilience since the year 2002. Table 1 presents the main stakeholders involved in flood resilience in Sebeya catchment and their respective roles. LAFREC program is about building resilience to flood hazards in North-West Rwanda through improved national and local capacity. Its objective is to improve flood risk forecasting and disaster preparedness by providing key technical studies, training, and guidance. LAFREC activities are expected to enhance early warning systems for at-risk communities and to help develop and implement flood mitigation measures with appropriate disaster risk reduction interventions in selected communities and sectors. The grant amount for LAFREC activities is 450,000\$, activities started in October 2017 and will be completed in April 2019 (GFDRR, 2018). In 2017 the Embassy of the Kingdom of the Netherlands (Ministry of Environment, 2018) funded a \$ 22bn project to preserve Sebeya and other catchments in Rwanda which is called the Landscape Restoration and Integrated Water Resources Management (IWRM) in Sebeya and other Catchments. The project is being implemented by Rwanda Water

and Forestry Authority (RWFA) in collaboration with International Union of Conservation of nature (IUCN), Netherland Development Organization (SNV), and Action for the Protection of the Environment and Promotion of the Agricultural Sector (APEFA). According to one of the mandates of RWFA, Water department is developing and operationalizing a (specific) flood early warning system for the Sebeya basin, including an integrated hydrological and hydraulic flood forecasting.

Table 3: Stakeholder Matrix

STAKEHOLDER	MAIN INTEREST	ROLE	TYPE	LEVEL	CHARACTERISTICS	INTEREST & POWER
RIPARIAN COMMUNITY	Houses ownership	1	1	2	Planning	High Importance/ Low Influence
FARMERS	Agriculture land (tea plantation, other crops)	1	1	2	Planning	High Importance/ Low Influence
MINEMA	Mitigation Measures	1	1	1	Management	High Importance/ High Influence
MOE	Environmental stewardship	2	1	1	Monitoring and evaluation	High Importance/ High Influence
REMA	Environment restoration and regulation	2	2	1	Management/ Policy enforcement	High Importance/ High Influence
LAFREC	Flood Forecast and Preparedness	2	2	1	Development	??
FONERWA	Fund for protection of 10 meters setting up bamboo plants	3	2	2	Financing	Low Importance/ Low Influence
DISTRICT OFFICE	Support in implementation	1	2	1	Development	High Importance/ Low Influence
RWFA	Flood forecasting, real time flood gauging and flood modelling	3	2	1	Development	Low Importance/ Low Influence
IUCN	Implementing 2018 FMP	3	2	1	Development	Low Importance/ Low Influence
SNV	Flood Recovery	3	2	2	Development	Low Importance/ Low Influence
RED CROSS	Flood Recovery	3	2	1	Recovery	Low Importance/ High Influence
RMA	Development of precipitation forecast	3	2	2	Development	Low Importance/ High Influence

Source: Information compiled from (GFDRR, 2018), (MoE, 2018)

Legend of the Matrix

Role = 1: Affect and affected 2: Affected 3. Interested
 Type = 1: Primary (Beneficiaries) 2: Secondary (Interest in the project)
 Level= 1: Active (Decision maker) 2: Passive (Affected by decisions)

2.6. Theoretical Conceptual framework

Overall theoretical material gives this study a room to conceptualize a framework of flood resilience strategies for Sebeya catchment. With the mixture of existing resilience techniques, the participatory approach and the GIS based interactive map. Assessments of resilience starts from participatory approach to build resilience strategies put the resilience in place and design

them in web platform and allow the community to monitor them via a cloud-based reporting system.

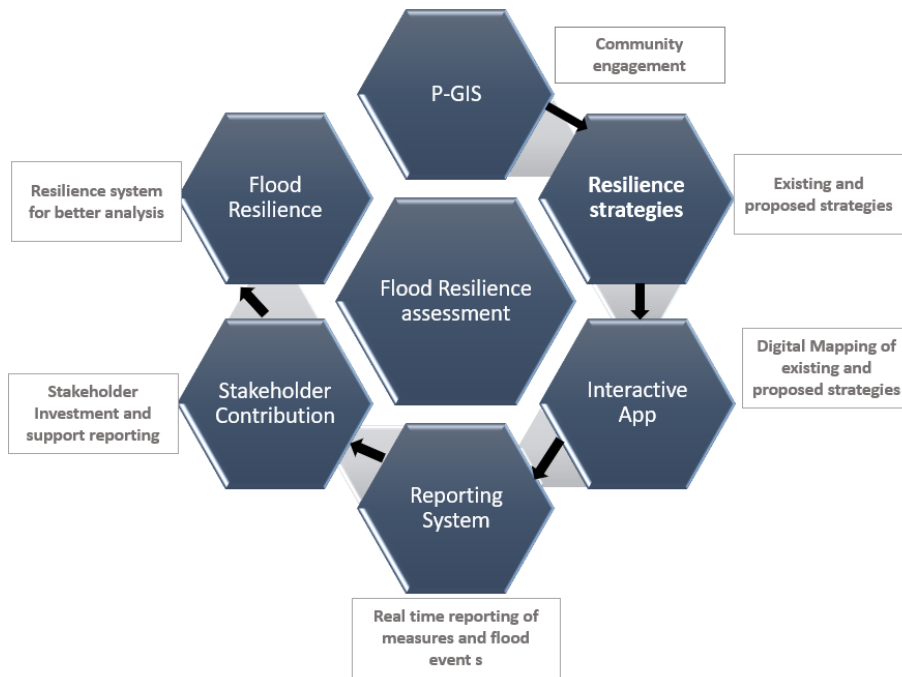


Figure 3: Flood Resilience Assessment Conceptual Framework

The figure 3 represents a concept which can be used to involve the riparian population in reporting flood resilience techniques via a reporting system which in real time communicate with the interactive map to inform stakeholder. Then the interactive map could ease the assessment of what is in place and help to identify the right household or right area which need action.

2.7. Summary of the chapter

The chapter defined in different way flood resilience and flood resilience strategies. There are infinite numbers of flood strategies in the world, from the most used and popular we were able to cite and define seven flood resilience strategies. It is important to note that different techniques can be combined for efficient risks reduction. Nonetheless to achieve the implementation of the strategies, community participation is one of the key. Participation based on mapping or again participatory GIS as a smart and efficient way to engage the community. The smart GIS engagement can be done via interactive maps and report systems to inform stakeholders and ease decision making. Stakeholders need to have the same language since they have the same objectives thus a common platform to assess flood resilience could be a platform to avoid redundancy and put effort where it is needed.

CHAPTER III. RESEARCH METHODOLOGY

Assessing flood resilience means engaging people living in the area, have a contact with stakeholders in the area in order to get well informed. Thus, the main data collection involved the population. This chapter mainly explains the method of data acquisition. This section will explain methods used like Interview; Survey questionnaire, Focus Group discussion and development of Interactive digital map

3.1. Description of Study Area

Rwanda disposes of six known big water catchments which are Nyabarongo catchment (3,305 km²), Mukungwa catchment (1,887 km²), Rusizi catchment (1,005 km²), Muvumba catchment (1,565 km²), Akanyaru catchment (3,402 km²) and Lake Kivu catchment (2,425 km²) (RNRA, 2014). Sebeya catchment is a sub-catchment of Lake Kivu catchment with a surface area of 286 km² straddling Rutsiro, Rubavu and Ngororero districts. The catchment is composed of four rivers: Sebeya is the longest with 113 km; Bihongoro with 42 km; Karambo with 33km and Gisunyu with 2.3km. Sebeya River which takes source in the mountains of Ngororero and Rutsiro District, meets many tributaries in Rubavu District. Some of those tributaries are Bihongoro, Karambo, Kagera, Gisunyu, Yungwe and Bukeri streams. Most of them take source in Gishwati-Mukura National Park and put a lot of pressure on Sebeya River since they flow on steep slopes. Elevation in the catchment varies between 1,460 and 2,000m in the western part, to 2,000 and 2,220m in the center, and from there rapidly increases to the top, eastern side, up to 2,950 m (MoE, 2018). Sebeya catchment has abundant water resources due to high rainfall. Sebeya catchment is characterized by two wet seasons and two dry seasons as where a small rainy season start from mid-September to mid-December; a short dry season start from mid-December to mid-February; a great rainy season start from mid- February to May and a long dry season start from June to mid-September.

The catchment hosts near 250.000 people with Nyundo and Kanama sectors area highly populated with 30,417 people (ENTREM Ltd, 2018),the population is attracted to Sebeya catchment due to its physical characteristics like fertile soils and climate which attract large firms of tea plantation, modern grazing areas; valuable historical sites like the Roman Catholic Diocese of Nyundo; presence of secondary city; presence of schools and health centers, paved roads, presence of minerals that can be mined; existing hydropower, water treatment plant and opportunities for further development.

In this research, four administrative sectors were chosen because they are area of focus for flood preparedness and forecast for LAFREC project. Those are Kanama, Nyundo, Nyakiriba and Rugerero sectors. The four sectors are very populated in terms of habitants and activities. They have recently experienced flood hazard according to the (IFRC, 2018) in Kanama, Rugerero, Nyakariba and Nyundo sectors damages were reported around 5,000 households (around 25,000 people) from 7 cells of the four sectors were affected by the floods, of which 4,750 people from 950 households were directly affected and the 950 homeless families were accommodated in the nearby communities after their homes were either destroyed or badly damaged by flowing waters and mud debris.

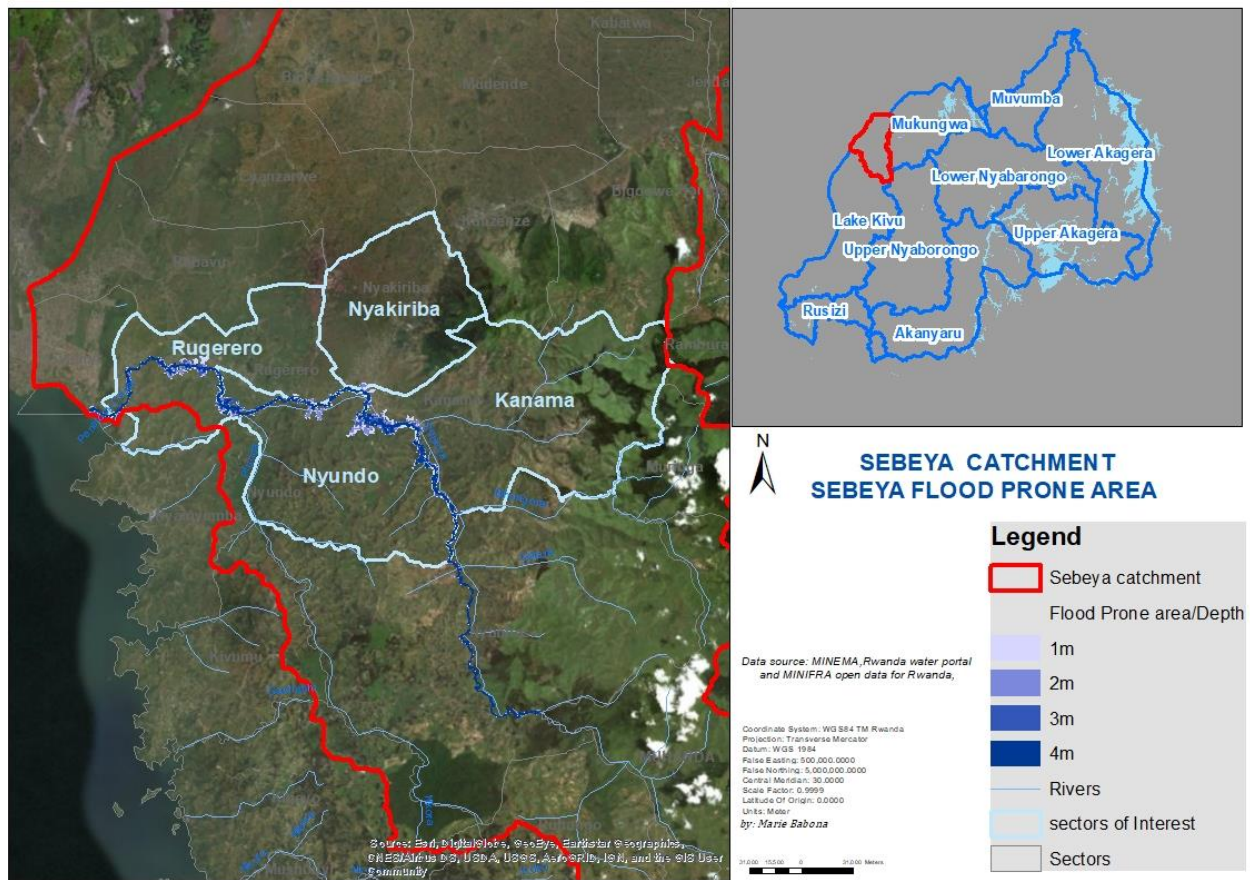


Figure 4: Study Area Map

3.2. Data collection

In data collection, desk review, interview, household survey and Focus Group discussion have been used.

3.2.1. Secondary data collection

General understanding on flooding and techniques for mitigating their effects were collected from different published materials. Some documents were found in library and documentation units like research gate, Google scholar, websites of public institutions and open data portals. Other important documents were provided by the Direction of DRR at MINEMA. The report presents the causes of flood risks and damages and resilience interventions in place, mentions areas more affected in Mahoko, Nyundo and Rugerero, and finally explores possible other solutions to flooding. These include among others, setting up an adequate early warning system.

Key data on areas that are flood prone in Nyundo sector were compiled from other studies. Flood prone area of Sebeya river was acquired from Rwanda Disaster Risk Atlas (MIDIMAR, 2015) and shapefile was accessed from RCMRD Portal (RCMRD, 2018). The flood zone was developed using GIS Flood Tool (GFT) implemented through the Manning equation which analyses flow patterns of water surface shape, velocity, shear stress and discharge through a stream. A 2019 drone imagery and DEM data was provided by REMA. Other data were found on existing open data platforms in Rwanda and living atlas worldwide GIS platform. Data on land parcels located in the area of my interest were provided by Rwanda Land Management and Use Authority (RLMUA).

Table 4: Sources of spatial data used

Data type	Owner
Rwanda Administrative boundaries	NISR Portal
Sebeya Flood Prone area	RCMRD Portal
Sebeya Catchment boundary	Rwanda Water portal
High Resolution Image and DEM	LAFREC drone release images
Rwanda parcels	RLMUA

3.2.2. Primary data collection

Primary data have been collected through semi-structured interview with staff of MINEMA, image processing, household survey and Focus Group Discussion (FGD).

3.2.2.1. Interview with key informants

A semi-structured interview was given to the Director of department of flood prevention in MINEMA to get the information about past flood experience and interventions within Sebeya catchment. The interview was held at MINEMA premises on August 2019. Another interview was planned to be held with Nyundo Cell executive secretary to get information about flood resilience strategies in their cell and experienced damages, but she did not manage to avail herself for that session.

3.2.2.2. Household survey

A. Sampling technique

For household survey the area of interest (Nyundo, Kanama, Rugerero and Nyakiriba Sector) was split into clusters for better efficiency of sampling.

Cluster method is defined as a technique in which groups of participants that represent the population are identified and included in the sample. The cluster sampling has proven its efficiency for large geographic area. The method is used when the data present existing natural groups. In our case study we used a multiple stage cluster sampling which is used for conducting effective research across multiple geographies, one needs to form complicated clusters that can be achieved only using the multiple-stage sampling technique, groups are chooses using different criteria or characteristics (Fleetwood, 2020). We based the groupings choice on three existing natural grouping which are sector level, cell level and village level. Flood occurs in the four sectors however not in the entire area according to the flood prone area map. To be closer to the flood prone area, the cluster was chosen at village level and three clusters were chosen among the 170 clusters. Different criteria were used to identify the three clusters among them we choose area:

- ✓ Falling in the high flood depth zone (possible flood experience)
- ✓ The area with high density building (possible higher exposure)
- ✓ Their past experiences with flood events and damages

Clusters were chosen at village level in Nyundo and Kanama sectors. The three villages are Gasenyi, Kiziguro and Mahoko respectively in Nyundo and Kanama sector.

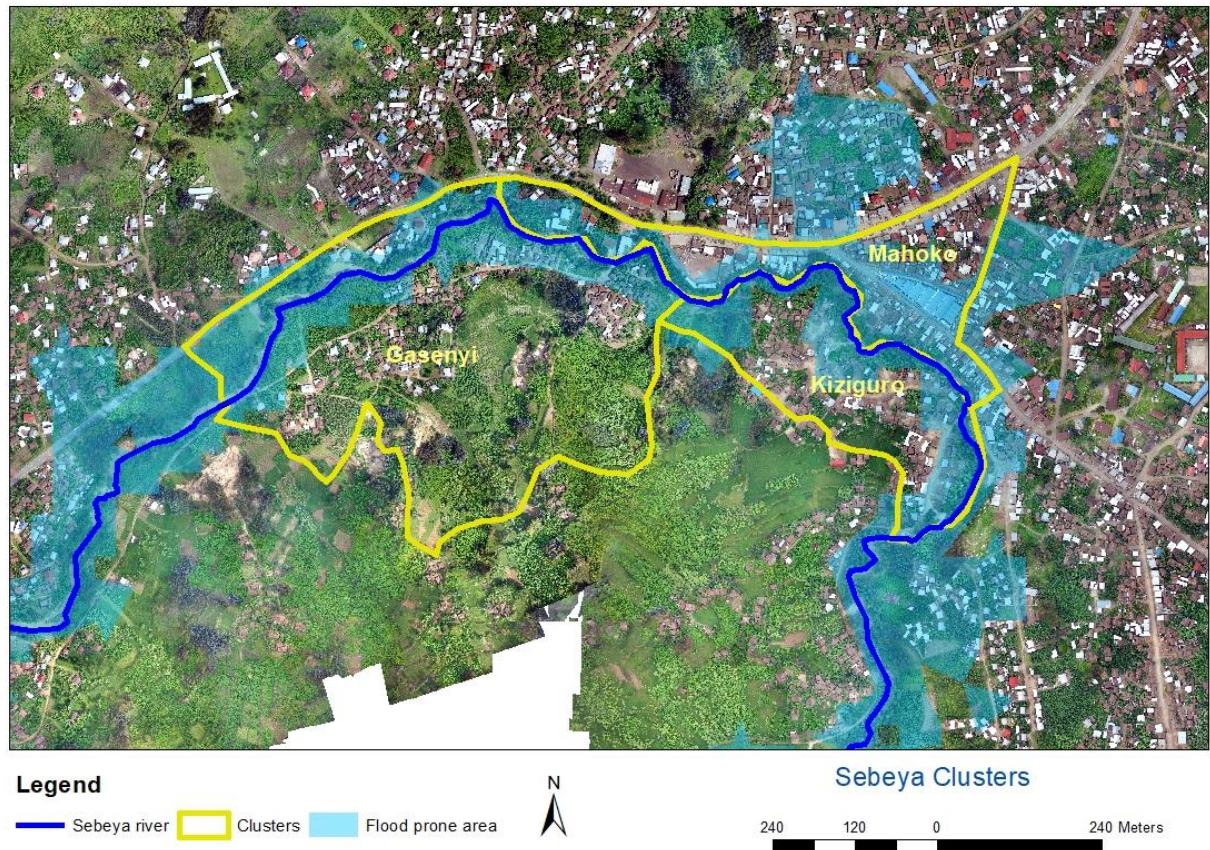


Figure 5: Location of clusters

Within our multiple stage clusters, we planned a census of each parcel. We were able to visit the parcels and meet representatives of houses. However due to high density of houses, the fact that people live very close to each other it was difficult to isolate each person per houses therefore people were interviewed in some cases in group and data was aggregated to the nearest parcel, those parcels were classified as. Some buildings were classified as inaccessible, destroyed (4) or Vacant (3). In total out of 474 land parcels identified finally we were able to survey 316 individual land parcels which is 66.6% of the total land parcels. The survey ran from August to September 2019. Two enumerators were recruited, were explained the survey questionnaire and trained on data capture using Survey123 and collector for ArcGIS on tablet.

B. Household survey process

With the P-GIS the local community helped to show resilience strategies put in place by different stakeholder's projects. Population living around Sebeya could show the more vulnerable places thanks to their knowledge on past flooding events; they helped to allocate or validate the proposed resilience or coping capacities measures.

The Participatory GIS which involves population views and use of mapping were done using a survey questionnaire method which was administrated to a representative of each household exposed to flooding. The questionnaire used both Survey123 and Collector for ArcGIS. Survey123 for ArcGIS and Collector for ArcGIS are both field data collection application both available on Google play. Survey123 is a form centric which allows development of sophisticated forms with cascades, skip, multiple choices whereas Collector for ArcGIS is a map centric app which allow basic editing of attribute information (Ichivite, 2015). The collector was used to guide and automatically fill the form with Parcel data like UPI, Parcel ID and administrative data. Then a Survey123 form was used to collect data about flood causes, flood exposure, flood damages, flood resilience and pictures of the action taken.

3.2.2.3. Focus Group Discussion (FGD)

The objective of the focus group discussion was to get information about how efficient methods was put in place by the community and stakeholders on one hand and gather information on the best suitable mitigation methods that the local community would apply to mitigate flood impact. The FGD intended to get this key information from the local population. The probe questions were asked to the participants focused on:

- Population's perception about flood risk,
- Resilience techniques in place and their efficiency,
- Population's viewpoints on Sebeya deviation and the creation of an artificial lake, and
- Possible resilience strategies to put in place.

The preparation towards the FGD started in mid-September when contacts were made with both representatives of Nyundo and Mahoko Cell through a phone call to inform them about the willing to conduct an FGD on flood risk within the respective village we visited. On phone a summary on the work done previously on resilience within their respective villages was mentioned and the category of people we would like to meet. The 28th September 2019 was agreed for Nyundo Cells to conduct the FGD after the community work and Mahoko on 29th September 2019 with for both 20 participants for each FGD living in our clusters with living experience of the area.

After *Umuganda* (community work), Cell representatives introduced me and objectives of the discussion to the population, he thereafter asked the 20 people who were contacted to stay for a

discussion. The 20 people were a group of 8 females and 12 males aged between 35 and 68 (reference to their presentation). After listening to the topic to be discussed, the remaining population who were in *Umuganda* insisted to stay and assist to the discussion. In total, 36 people participated in the discussion. The FGD was done at Nyundo Cell Office on 28th September from 10:00am to 3:00 pm with people from different villages (Gasenyi, Kiziguro and Kibaya). Introduction of the subject and the overview of the survey were done on each village one month before. In total 20 maps were prepared and printed in advance to guide the participants to identify area assessed. The participants were able to give their concerns about Sebeya flood. Some participants gave suggestions on best resilience techniques in the area while others in the audience were able to supplement them, agree or disagree with their suggestions.



Figure 6: Focus group discussion sessions

The photos on figure 6, represent participants using paper maps to show and draw area with emphasis on the area with problems and methods in place D. Participants proposing the relocation A and deviation of the river B, the chief of Nyundo Cell listening to the suggestions and comments C

The second part of FGD from 12pm to 3pm was done with six volunteers. We walked around the three clusters to see in situ facts of what was discussed. We walked two hours around the village identifying problems reported, the proposed solutions, mostly solution given on the deviation of the river and artificial lake. We went all over the river meanders of Sebeya river within Kiziguro and Gasenyi village. At the end we were able to sit down draw on map all the options proposed. At the end of the discussion, different community resilience strategies were developed and mapped.

3.2.3. Image processing

Image processing in this study consisted in extraction of building footprint from 2019 drone release imagery with 5cm spatial resolution.

3.2.3.1. Building footprint digital data extraction

In order to have the right number of buildings which are exposed to flood prone area, we used a digitization method to extract one by one building footprint in the study area. The extraction was done on a high-resolution drone imagery with GIS software. The object-oriented supervised classification using segmentation techniques as training strategy did not give accurate building footprint, most of the houses had the same characteristics with the bare land and the process of reclassification would have taken longer than a manual digitization. Consequently, the building footprint was extracted manually. The building footprint extracted was then used to identify the corresponding parcel. The process to identify corresponding parcel from constructions footprint was done by identifying the spatial interaction between both constructions' footprint shapefiles and cadastral parcel shapefile, then the intersecting parcels were extracted as standalone shapefile (Figure 7).



Figure 7: Parcel identification and extraction

3.2.3.2. Identification of household flood level

The level of exposure was found by overlapping the flood prone area with the buildings. The level of flood exposure was created using three parameters: flood depth, slope and elevation. Since some of the houses from the survey were reported to have experienced flood damages, we created a buffer zone on the existing flood zone which we gave 5 levels of exposure to flood where level 1, 2, 3, 4 and 5 correspond to area which experienced respectively flood depth of 0.5m, 1m, 2m, 3m and 4m. Once this process completed, it was possible to calculate the level of exposure using the above indicators as defined in table 5.

Table 5: Flood exposure indicator

Exposure Level	Parameter		
	Flood depth (m)	Slope (%)	Elevation (m)
Very Low (1)	Between 0.5 and 1	>30	>1,800
Low (2)	Between 1 and 2	>30	>1,800
Moderate (3)	Between 2 and 3	16< >30	<1,800
High (4)	Between 3 and 4	<16	<1700
Extreme (5)	Above 4	<9	<1700

3.4. Data processing

Interview were summarized into text and answer from the Focus Group Discussion where represented by theme into graphs and Maps. Maps from FGD were scanned and georeferenced into IRTF 2005 then symbolized in GIS software. Thus, both the survey and FGD were automatically readable into a configured web dashboard to reveal pattern on the data and ease the creation of graphs.

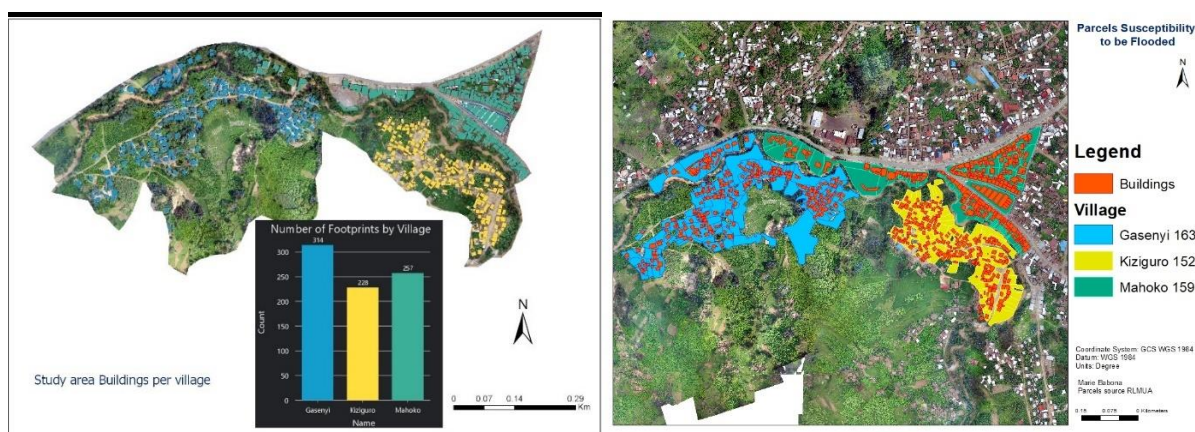
CHAPTER IV. RESEARCH RESULTS AND DISCUSSION

This chapter represents results on flood resilience strategies already in place in the study area. It furthermore shows exposure and population's perception on causes of flooding and possible other mitigation strategies.

4.1. Building Exposure to Flood

4.1.1. Number of buildings in the three villages

In total, 801 houses were identified: 314 houses in Gasenyi village; 228 in Kiziguro and 257 in Mahoko. Those constructions were recorded in 474 land parcels distributed as follow: 163 parcels in Gasenyi, 152 in Kiziguro and 159 parcels in Mahoko. Figure 8 shows houses and parcels containing the clusters

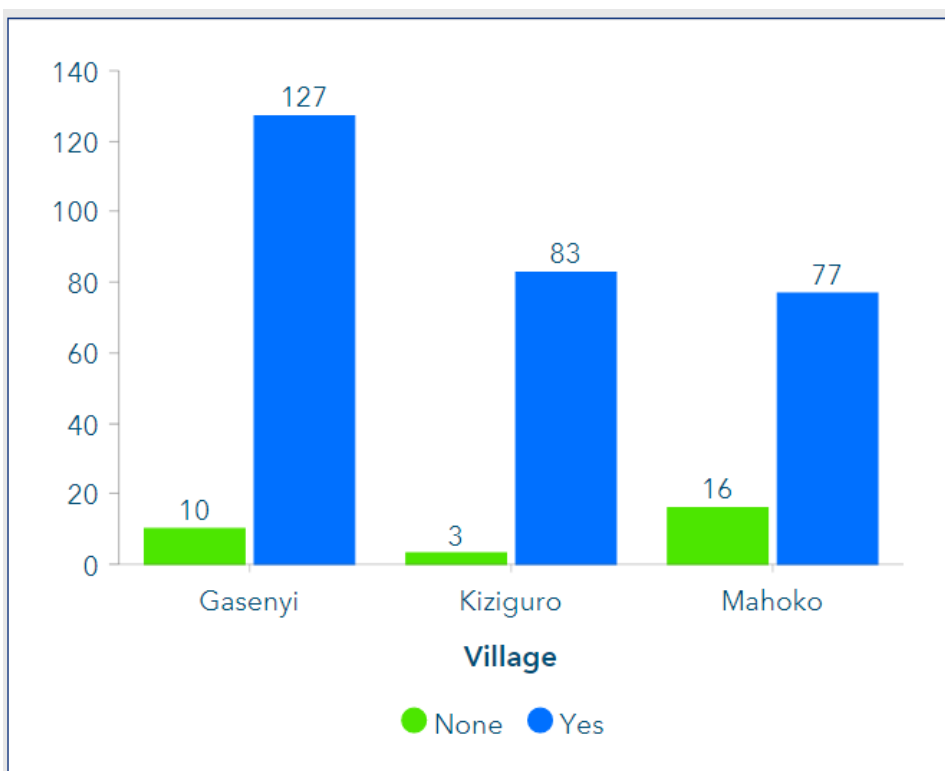


Source: 2019 REMA drone release imagery and parcels from RLMUA

Figure 8: Exposed constructions/footprint and their corresponding land parcels

4.1.2. Houses that experienced floods in clusters

The survey revealed that out of 316 parcels surveyed, 287 (91%) have experienced flood while 29 (9%) reported to have never experienced flood damages. As reported in the figure 9, Gasenyi is the cluster with more experience in flooding with 127 (44%) houses reported to have experienced flood and Kiziguro reported 83 (29%), Mahoko 77 (27%) of house parcels which has experienced flood in the past.

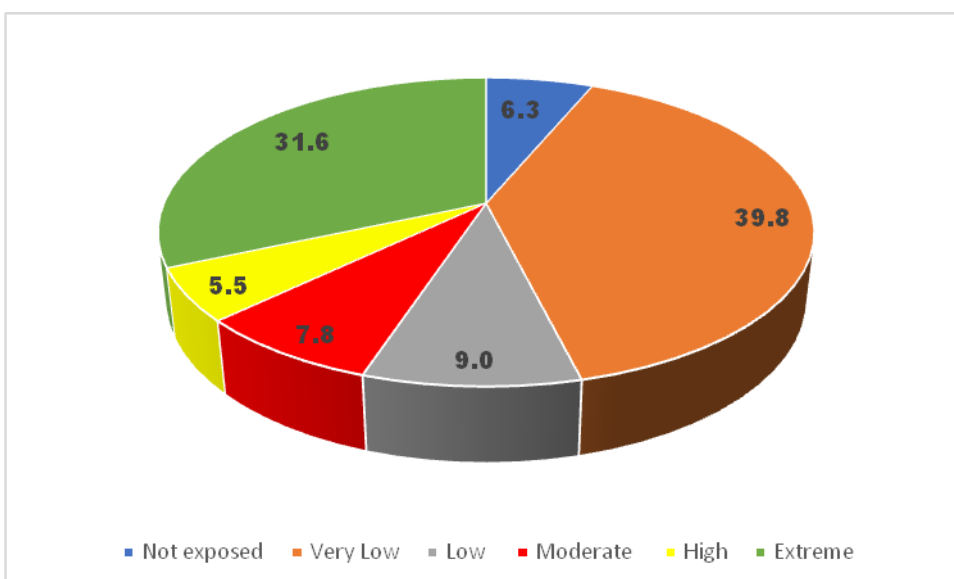


Source: Household Survey

Figure 9: Number of households which have experienced flood

4.1.3. Buildings' exposure to flood

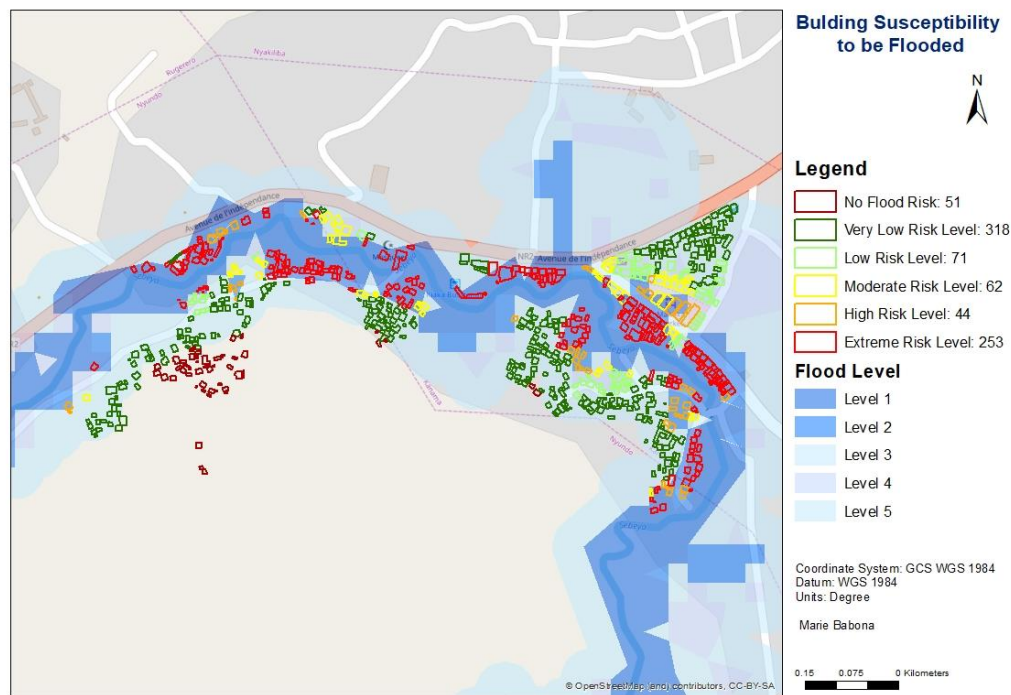
Building's exposure to flood in Sebeya was confirmed through the survey (see sub-section 4.12.) Exposure to flooding is itself interesting but the level of exposure is more interesting and informative for designing appropriate measures. The level of exposure to flood was assessed with the use of a flood exposure model build based on flood depth combined with elevation and slope. The model revealed that houses are not exposed at the same scale. The situation is critical for 37.1% of houses where flood can reach up to 3m and above.



Source: Household survey, September 2019

Figure 10: Number of houses (%) per level of exposure

As of location of exposed houses, Figure 11 shows that houses that are extremely and highly exposed to flood are closer to Sebeya river. The less exposed houses are found relatively distant from the river.

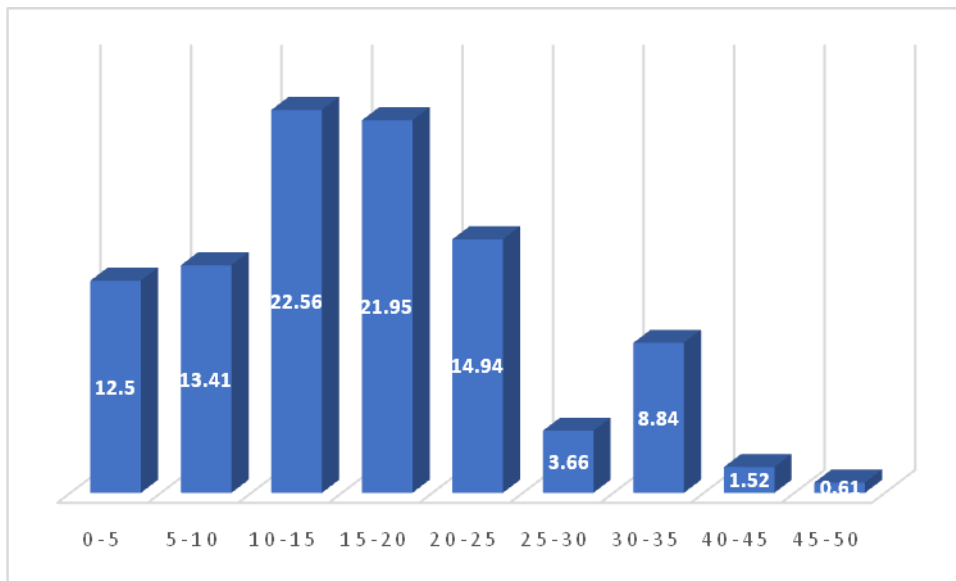


Source: 2019 drone imagery

Figure 11: Exposure of houses

4.1.4. Period of the settlement in the area

As exposure to flood was found very high in the area, respondent were asked for how long they have settled in the area. From the survey it was found that most of the respondents (44.51%) have been settling in the area for a period comprise between 10 and 20 years while people who have settled in the area for more than 25 years represent 14.9% (Figure 12).



Source Household survey

Figure 12: Distribution of respondents (%) per length of stay in the area prone to flood

Some respondents stated that their parents were residing in the area, they themselves inherited the land and they are still living there. According to the results from the survey it appears that settlements in area have been exposed to flood for a long time and people have been able to manage living with flood by putting in place some measures to protect themselves and taking risk of their life. Exposure is not new for the people who have stayed in the area for this long period.

4.2. Flood Resilience techniques in place

Concerning resilience techniques in place, the director of the department of Disaster Risk Reduction at MINEMA provided information on Sebeya river about interventions done for flood preparedness and mitigation measures. According to him, the Ministry has done much in terms of flood resilience within Sebeya catchment. The Ministry works with many stakeholders to mitigate and reduce flood risks in the catchment. Stakeholders include Meteo Rwanda, RWFA and Rubavu District. Meteo Rwanda has the mandate to provide timely accurate information that is specific to the zone which may be mostly affected by hydro-meteorological hazards in order to improve the early warning system. RWFA has the responsibility to develop the Catchment Plans Rehabilitation and provide information from gauging stations to MINEMA. The Ministry also works closely with Rubavu District on possible relocation of all the population living in the area prone to flood as well as the commercial activities in Mahoko Centre. The Ministry and the

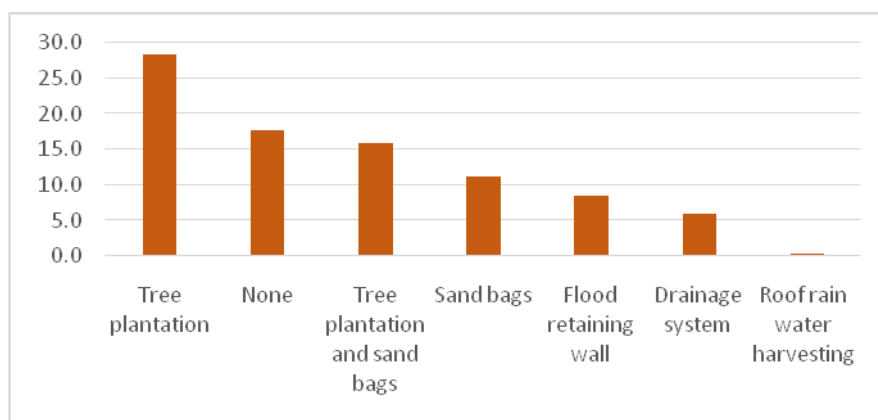
district also organize community works and work hand in hand to stopping illegal mining and sand extraction around Sebeya river.

4.2.1. Proportion of protected buildings

The survey done at parcel level revealed that most of buildings in the cluster analyzed have at least one mean of flood resilience. In total, out of parcels visited, 71.63% of respondents have stated that they have put in place a resilience technique, 22.06% said that they have no flood resilience technique in place due to the lack of money and knowledge and 6.3% did not respond to the question, because they were living out of flood prone area

4.2.2. Type of resilience techniques in place

There are many techniques used for flood resilience. Figure 13 shows techniques adopted by the residents to cope with flooding. The most used are trees plantation (28.4%), trees plantation and sand bags together (16%) and sand bags alone (11.2%). Other techniques are used by less than 10% of the respondents.



Source: Household survey

Figure 13: Existing flood resilience techniques

As of tree plantation, huge number of trees has been planted since 2016. The government of Rwanda has helped planting a strip of 10m on both side of Sebeya river in Nyundo and Kanama sectors. Sand bags are used in two different ways: on one hand, sand bags are used at household level to prevent water to entering into the house or plantation, on the other hand sand bags are piled along the river banks to prevent Sebeya overflow. Tree plantation can also be associated with sand bags. At field visit, it was also observed that some households use to dig holes in front

of their houses to retain the overflow water from Sebeya, thus dug holes river have similar roles as cesspool found in urban areas.



Source: Photo taken by the author on 10/08/2019 during field survey

Figure 14: Techniques for flood resilience

Other structural methods which are more engineering methods are also employed in coping with Sebeya water overflow. These include lava stone walls, gabion retaining wall and cemented retaining wall. Some families used to pile lava stones in front of their housing to protect them from flooding risks. Cemented retaining wall are found around bridges where there are important infrastructures like schools, tarmac roads and health centers (see Figure 13 B, C)



Source: Photo taken by the author on 10/08/2019 during field survey

Figure 15: Structural techniques for flood resilience

The non-structural methods used by the community is the organisation of the community in terms of flood warning. In present days, when it rains, men stay awake to observe water level in Sebeya river. When it reaches alarming level, they then use whistle to alert the community about

possible inundation. Respondents said that the local population is still waiting for more efficient early warning system which is supposed to be put in place by LAFREC project.

4.2.3. Stakeholders' contributions in mitigating flood

The survey revealed a long list of stakeholder organizations that have been involved in putting in place flood resilience methods. These include the Rwanda Red Cross reported by 34% of the respondents, Government of Rwanda reported by 14.8% and Care international mentioned by 15.2% of the respondents surveyed, the LAFREC project was also cited but few people knew about the project (only 12 respondents). Strangely, 11.1% of the respondents said that they did not know about the institution who contributed in supporting Sebeya in flood resilience. Rwanda Red Cross is the most known by the population due to its support to the population after flood occurrence. The Government of Rwanda has supported people living in the area before, during and after flood occurs. It is the one which put in place more means in regard to flood resilience. Before flood occurrence the government supports the population in building their resilience by increasing population awareness on flood and planting trees. During flood event, the government provides emergency and support to people exposed. After the flood the Government contributes in the relocation of destructed household. Details on kind of interventions are shown in table 6.

Table 6: Population awareness on stakeholders involved in flood resilience

Stakeholder	Interventions for affected households	Respondents
Rwanda Red Cross	– Provision of first aid like blankets, clothes – Provision of construction materials like cement, iron sheets	158
MINEMA/Government	– Leading campaign awareness on flood and share information and advices on best practices to mitigate flood, – Financing relocation operations, bags for sandbagging, planting trees, – Provision of construction materials like iron sheeting, nails, etc.	108
District	– Leading campaign awareness on flood and share information and advices on best practices to mitigate flood, – Support tree plantation, give cement, sheets, bags for sandbagging	58

	– Provision of construction materials like, cement, iron sheeting, nails, etc. – Provision of bags for sandbagging – Organization of community works for constructions of houses for households whose houses are destroyed or badly damaged	
Care International	– Provision of first aid like blankets, clothes, kitchenware, etc.	30
LAFREC	– Support tree plantation in Sebeya catchment – Provision of construction materials especially iron sheets	12
SNV	– Financing tree planting works	10
SONARWA	– Provision of construction materials like iron sheeting, nails, etc.	3
MINALOC	– Provision of construction materials like iron sheeting, nails, etc.	7

Source: Household survey

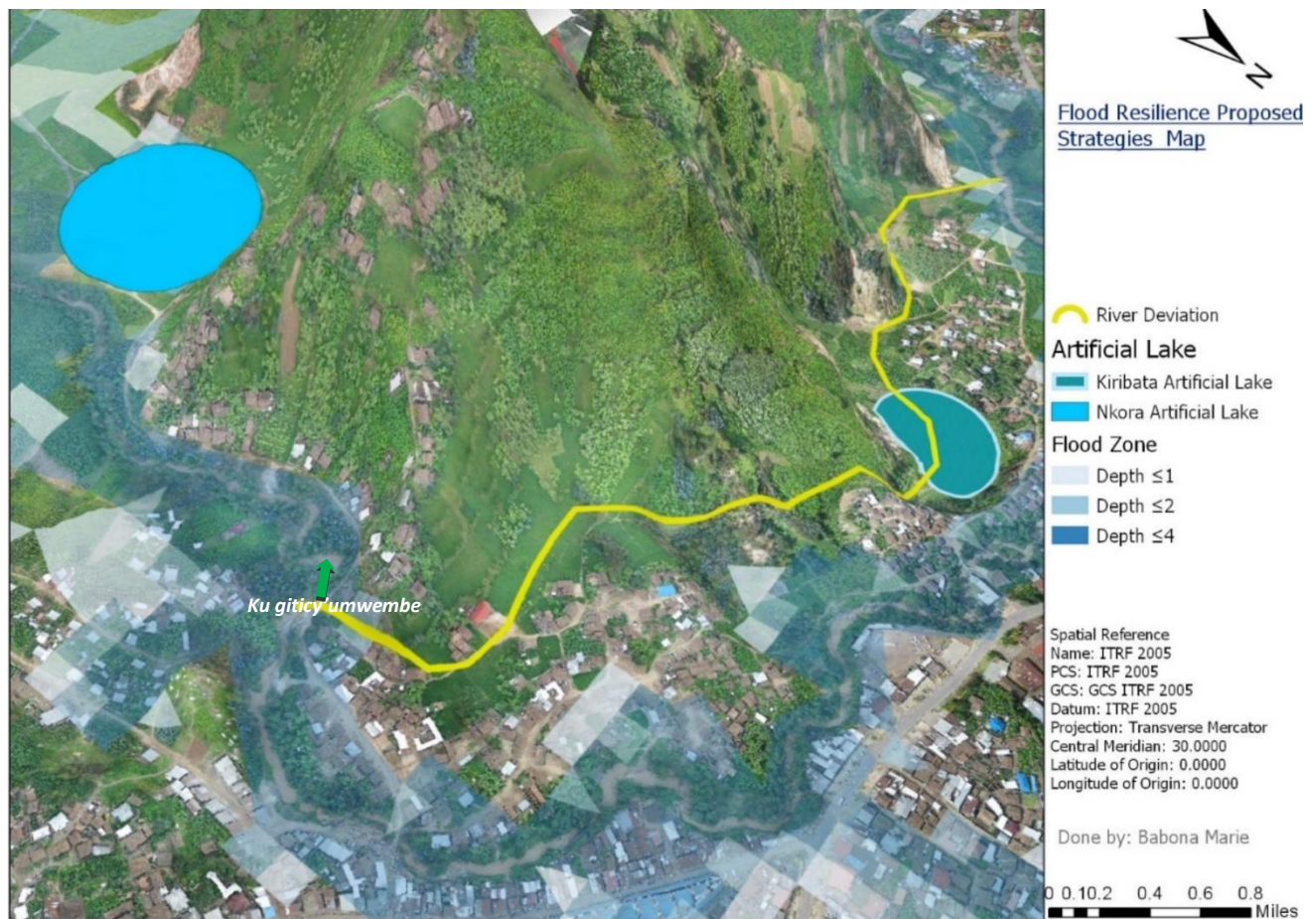
4.3 Proposed strategies for better flood resilience

The objective of the research was to know population views and opinions on methods in place and what would be the best practices to reduce or eradicate risks related to flooding. Participants in the FGD proposed a series of methods to adopt for better resilience to flooding. These include creation of artificial lake around tea plantation, removing all the meanders within the Sebeya river, deviation of Sebeya,, construction of underground tunnels, and levelling off Karambo mound.

4.3.1. Creation of artificial lakes around tea plantation

The first suggestion made by discussants in FGD was the enlargement of the river channel and creation of an artificial lake or dams on the side of Nkora tea plantation to reduce the water flow before it arrives in Kiziguro and Mahoko village. However, they mentioned that the area is covered by a very important tea plantation. They fear that the creation of artificial lake in that area would engender opposition from the tea plantation owners. Instead, the participants proposed another small space in the same area where a small artificial lake can be created (see

Figure 17). The same figure shows a second location where an AL can be created on the side of Gasenyi village. The AL will contribute to reducing the overflows in the vicinities and downstream of area.



Source: Focus Group Discussion

Figure 16: Proposed resilience techniques proposed by participants during FGD

4.3.2. Deviation of Sebeya

The deviation of the river is an idea which was shared by a big number of participants (86% of respondents during household survey). Most of participants in the FGD suggested the deviation of Sebeya. For them, the deviation of the river from Kiziguro village to Gasenyi village would reduce a lot in term of flood risks. The deviation of Sebeya implies the construction of a new river channel of 1.36 km long. Since water that inundates the three studied villages spill over at the locality called “*Ku giticy'umwembe*” (see Figure 16), participants proposed that the deviation of the river would start at that locality. For the participants, deviation of Sebeya river will be a more sustainable solution to reduce considerably flood risks in the three villages. Within the 3D map we were able to verify the feasibility of the deviation. The map shows that the deviation in term of topography was feasible sin the area chosen was in a valley (see figure 16).

4.3.3. Removing all Sebeya's meanders

The removal of meanders was supported by different people in different clusters. The removal of meanders would enlarge the river and reduce width of riparian crossing. The substantial changes in channel morphology would bring the water out of the built-up area thus reduce risks. Some participants were worried that the deviation would change dramatically the river system behavior and destruct some houses located on the course of the new channel.

4.3.4. Construction of underground pipes

The idea was moderately supported by participants. Most of the discussants said that Sebeya river has high velocity, therefore it would be costly to place underground pipeline pipes that can drain the area. Other participants feared that, since water is used in many activities, channeling Sebeya water through underground pipe would create water shortage in the community.

4.3.5. Leveling off Karambo mound

Some participants in FGD proposed leveling off Karambo mound would be a good solution to alleviate the impact of flood in the three villages. They said that if the rocks on Karambo mound were removed, river burst will not have the same impact as it has. Others said that, though the proposed solution would be good, none can predict exactly what would be impact of such measure since Sebeya is located in a volcanic region and any broke of rock can make the water flow in other areas and cause other disasters.

4.3.6. Retaining wall

Other people would like to protect the flood prone area by constructing a concrete flood retaining wall along the entire river. For them, the wall should be built in pleasant architectural to attract tourists. So not only the tee plantation and the Roman Catholic Diocese of Nyundo should attract the tourism but also the beautiful made in Rwanda flood wall should bring them to see how they have been able to manage flood risk and maintain the area. Another surprise was that none of the participants in FGD proposed relocation of people from the three villages.

4.4. Research discussion

The result of the focus group discussion and household survey shows that tree plantation and use of sandbags are not strong techniques for flood resilience, because they have a small impact on river discharge thus could not help to reduce flood in the area. Study done by Carrick, et al. (2018) say that forestation is a technique which is therefore more environmental advocacy and is made very attractive for societal benefits but there is very weak evidence that shows effects of tree cover on river discharge. This can be explained by the fact that even if from 2014 a huge increase in trees are seen around Sebya river, however the flood of 2018 was more devastating than the ones experienced before.

In Rwanda significant number of research have been done on flood especially by the Ministry of Disaster which in 2014 developed a Contingency Plan for floods and landslides (NCP) (MIDIMAR, 2014); in 2015 the National disaster risk atlas and in 2018 a new version of NCP was developed. All those documents inform mostly about flood prone area around the country, flood damages and mitigation measures (after flood intervention) taken. There is still a lack of well developed strategies for flood preparedness per each specific flood prone area. As we can see in this study there is a need to concentrate on the way to reduce flood risk before it happen by introducing hard engineering solution.

The study done by Katsuhama (2010) on the flood management in developing countries say that developing countries are more vulnerable to flood compared to developed countries due to lack of flood management infrastructure. Flood damage could be increased because of insufficient information due to lack of communication devices, less communication between stakeholders. According to this study two points are applicable in Rwanda and Sebya context: lack of resilience strategies and lack of communication between stakeholders. Most of the stakeholders are supporting the community with basic needs after flood occur. There is a need to structure the area of support to avoid overlaps in one area and gap in another.

According to the household survey people have lived in Sebya for many years. The majority have been exposed to flood more than 20 years. However besides the flood damages new occupants has settled in the area this past last 5 years. There is a lack of understanding of the risk of being exposed to flood. People are more attracted by the fertility of the area than being afraid for their life. According to the focus group discussion residents of Nyundo and Kanama Sectors they are not willing to be relocated because they value a lot their land in Sebya. This

information shows that it is time put effort on regulation of new constructions around the river. To keep the place livable.

Resilience is concept which today need technological innovation, the study shows that the population of Sebeya are ready for innovation. They believe that a more sophisticated methods will bring light and peace to their environment. Sharing information in a more concise way to remove gaps and concentrate on areas of priority. A holistic methods which shows resilience of the community at building level by using maps could bring a change on how people proceed and take decision on flood risk reduction. Adding spatial patterns will inform the new people who are willing to occupy the house to know the status of the house in terms of flood level and flood resilience strategies in place. The level of resilience could open an opportunity for people to get authorization of selling their houses even if the house is located in a flood prone zone

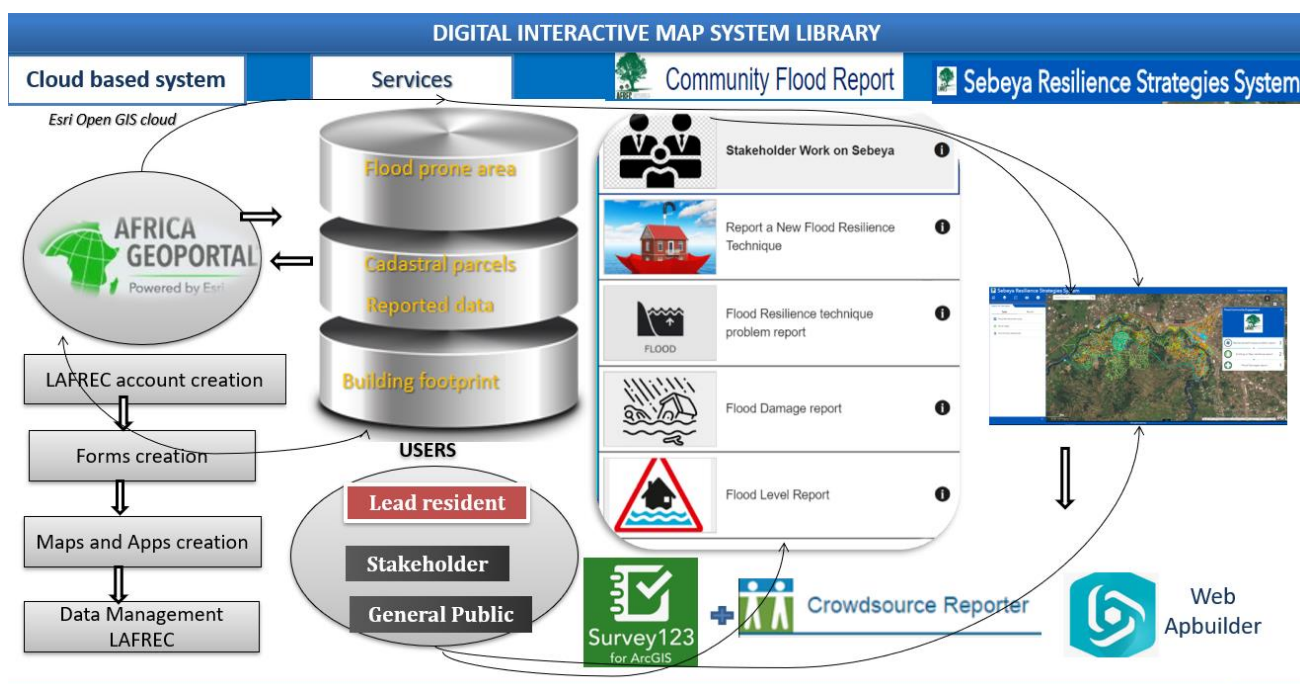
We cannot ignore the impact the use of engineering methods could have in eradicating flood risks. However we cannot also ignore that engineering methods implies disturbance of natural environment thus bring a fear to forget about the natural environment protection. The purpose of resilience being first environmental protection oriented, changing the natural course of living environment like when applying deviation of a river, stay a very sensitive if not alarming matter in terms of environment conservation. In the study done by Aristeidis and Mertzanis (2013) , diversion of a river may seriously affect the environmental balance of forests, wetlands, lagoons, and other ecosystems. So any disturbance which man made can easily cause a new environment problem. Nonetheless, both environment protection and human life are important at the same level, so the engineering work should not only prioritize the human life and forget about the protection of environment and should not also put environment first and forget that people need life. This being, there is a need analyse and balance all the engineering methods by predicting what and how each methods could impact in coming years.

4.5. Conclusion of the chapter

There are existing methods put in place by different stakeholders. They participate to reduction of flood risk, but they are not fully efficient. The discussants in FGD proposed a series of actions and measures that can be undertaken; however most of them are costly and could require time to be implemented. But to better know what is happening, a system of monitoring and evaluation that could help to monitor better flood occurrence and resilience is needed. This tool will be demonstrated in the next chapter.

CHAPTER V. FLOOD RESILIENCE DIGITAL INTERACTIVE MAP (FRDIM)

After the data collection, a Flood Resilience Digital Interactive Map (FRDIM) was created with web GIS technologies using ArcGIS open source for Africa. An account for flood resilience were created on Africa Geoportal¹ which is an Esri open source for Africa to share information and to bring out the insight of data by using online tools. We were able to upload all our data and create a web application using configurable Apps available with the platform (figure17).



Source : (Esri, 2020)

Figure 17: Digital Interactive Map System

5.1. FRDIM Inputs

Today thanks to internet connection around the world, sharing data is becoming much easier. As of flood resilience we have innovative way of reporting and monitoring flood. Rwanda has a lot of projects about flood going on, however they are scattered, it is time to put all the projects and initiative together on easy reachable platform for both population and investors or donors. Different studies and works done like the Sebeya catchment plan from Water for Growth, Sebeya flood forecast from LAFREC Project, the Disaster Risk Reduction department from MINEMA should share a common platform in order to efficiently bring solution to reduce flood and evaluate methods in place and mostly avoid redundancy in work done.

The contributors of this platforms are:

- Sebeya riparian community,

¹<http://www.africageoportal.com/>

- Stakeholders in flood resilience, and
- The general public.

The main data in the interactive map are:

- Flood prone area,
- Study area building,
- Cadastral parcels,
- Reported data, and
- Layer of proposed techniques.

Today it is difficult to easily share information when flood occurs, because there is no recognised platform or App where people can easily share information. The most known method of sharing information when flood hazard occurs is via social media like WhatsApp and Twitter. There is a need to create a flood-media App in order to involve the community of Sebeya and share real time information of what is happening and share their views.

5.2. FRDIM Output

The main output of the Interactive Map will be a series of different querriable parcels and resilience actions and real time visualisation of flood reports. The platform will comprise: community flood report data, buildings with flood resilience techniques, land use by parcel with UPI number, stakeholders work on Sebeya, proposed solution for Sebeya and open space preservation credit tool.

Community flood report data: Community flood report is a form for reporting flood events and reporting any resilience methods within the area on it's performance. The flood reporting system will be open to everyone with a smartphone or mobile devices with access to internet. The report form is developed using two different applications Survey123 and Crowdsouce reporter App. Crowdsouce Reporter is an Esri solution for local government which is a configurable application template that allows users to submit problems or observations through smartphones, tablets and desktop computers (Esri, 2015).

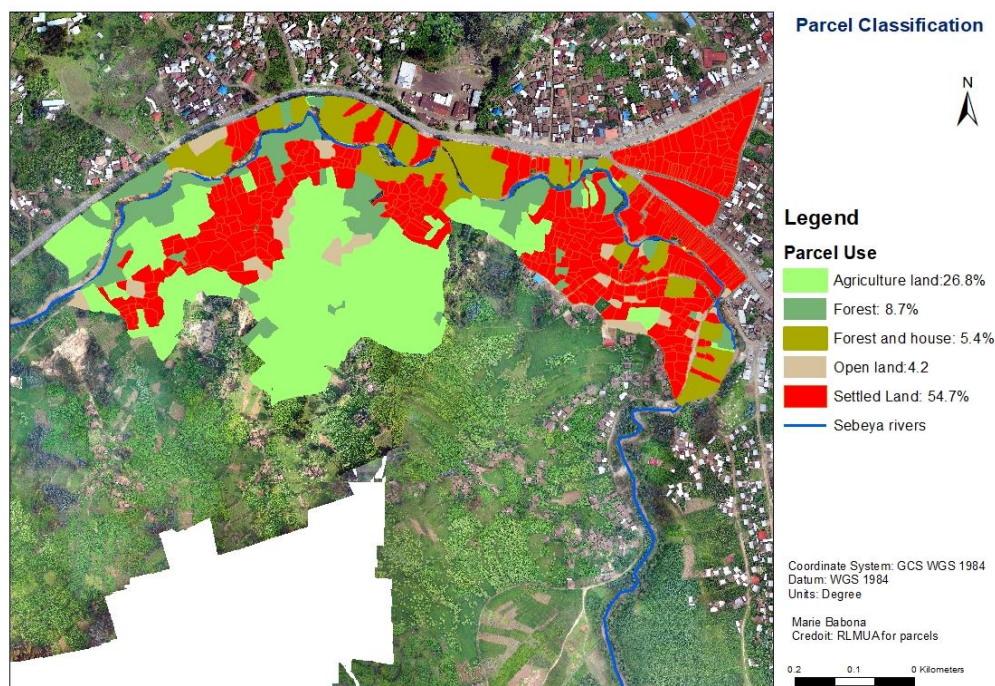
The Reporter App include different Reporter Forms:

- Flood event report,
- Damage report,
- Resilience Faillure report, and
- New resilience Report.

Forms are developed with a hosted feature layer with all required fields and domains. Then the feature layer is published as feature services on the open source portal. To allow creation of new problems and reports the service should allow creation for creating new issues, update to update existing information and delete to delete any report if it was an error. The layer is created using a survey123 App. Three feature layers were created and published all with the same privileges and they were shared to everyone so anyone could see the form and contribute to it, reference to the Appendix 2&3. The form allow users to login as guest, with a twitter account and login with credentials. The login with credentials is mainly for the flood lead resident.

Buildings with flood resilience techniques: The tool will show individual houses with resilience techniques in place. The colors on the map shows houses with resilience techniques (green color) and without individual techniques (red color). The map is feeded by survey done on field and will be feeded by the flood resilience technique in place reported by the flood lead agent on field. Once reported the color will be updated on the map automatically.

Land use by parcel with UPI number: Search of land use of the study area by categories (settlement, agriculture, forest and open land). The land use have been defined in four categories (forest, settlement, settlement with forest, agriculture and open land). The settlement with forest class was defined for parcels with an important area containing forest and at the same time contain or have a construction, most cases was found along the river. The parcel classification will show the update of the area in terms of parcel change detection.



Source: 2019 drone image

Figure 18: Sebeya land use by parcel with UPI number

Stakeholders work on Sebeya: The App will give spatial and general information about stakeholders work on Sebeya flood prone area in terms of resilience. The tool will encompass a form for stakeholders. Stakeholder's work on Sebeya will be separated into groups, the spatial work and the written work or projects. The spatial work done will be filled by stakeholders in form template and the pdf file will be uploaded referencing a village or area of action. The App will allow a query per stakeholder work on Sebeya and give both spatial and report where applicable.

Proposed solution for Sebeya : The App shows proposed resilience strategy put in place by the community and any research. The proposed solution will be displayed in the App in form of spatial or comment report from citizen or other reporters. A search by proposed solution will be developed by type and administrative area.

Open space preservation credit tool: The OSP is today a famous technique which has been introduced by the CRS program under the flood Science Center. The tool was designed to involve the community in the protection of environment. The purpose is to reward communities that maintain and/or protect the floodplain as open space, the rewards of people willing to participate could be managed by LAFREC project in Rwanda. In order to be classified as open space, the land must be "free from buildings, filling, paving or other encroachment to flood flows (CRS, 2016).

The open space preservation credits will help people to participate freely in propose their land for environment protection. The eligible people are people having their parcels available on the App and free of building. They should click on the parcel of interest and specify if they would like to use it for flood green space credit. The tool encompasses: parcel drawing, automatic email for request, attribute table to fill. A fixed html code was developed for the target population to send a direct email to LAFREC for the people interested to participate in the program

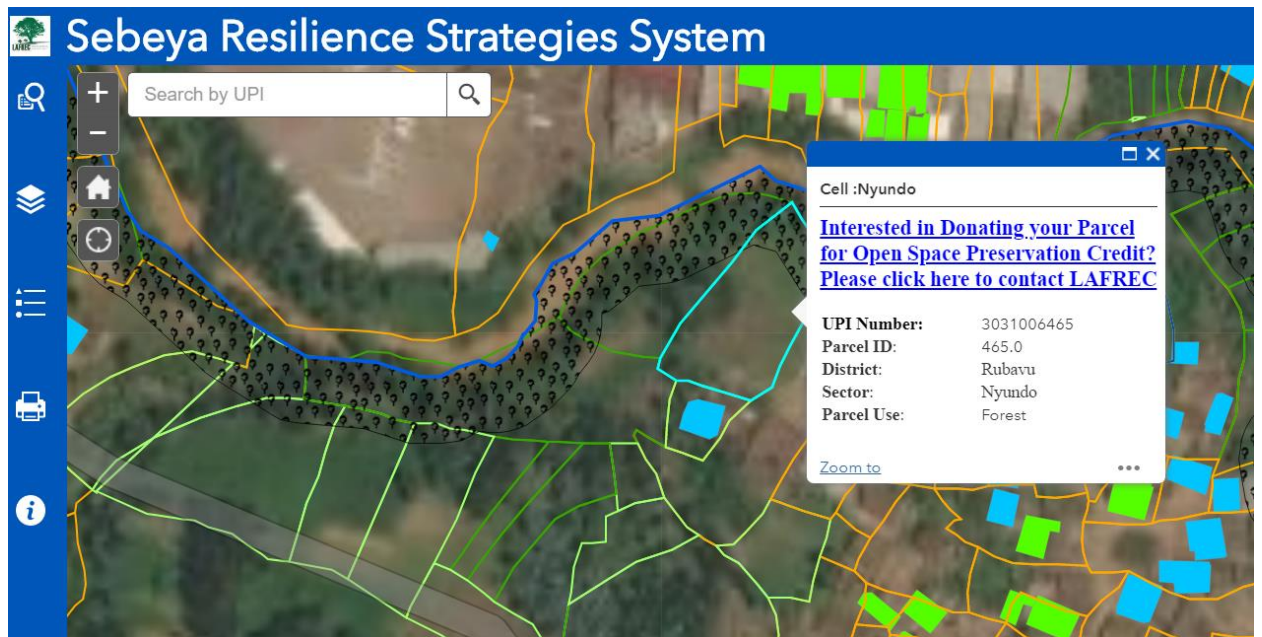


Figure 19: Open space preservation credit request tool

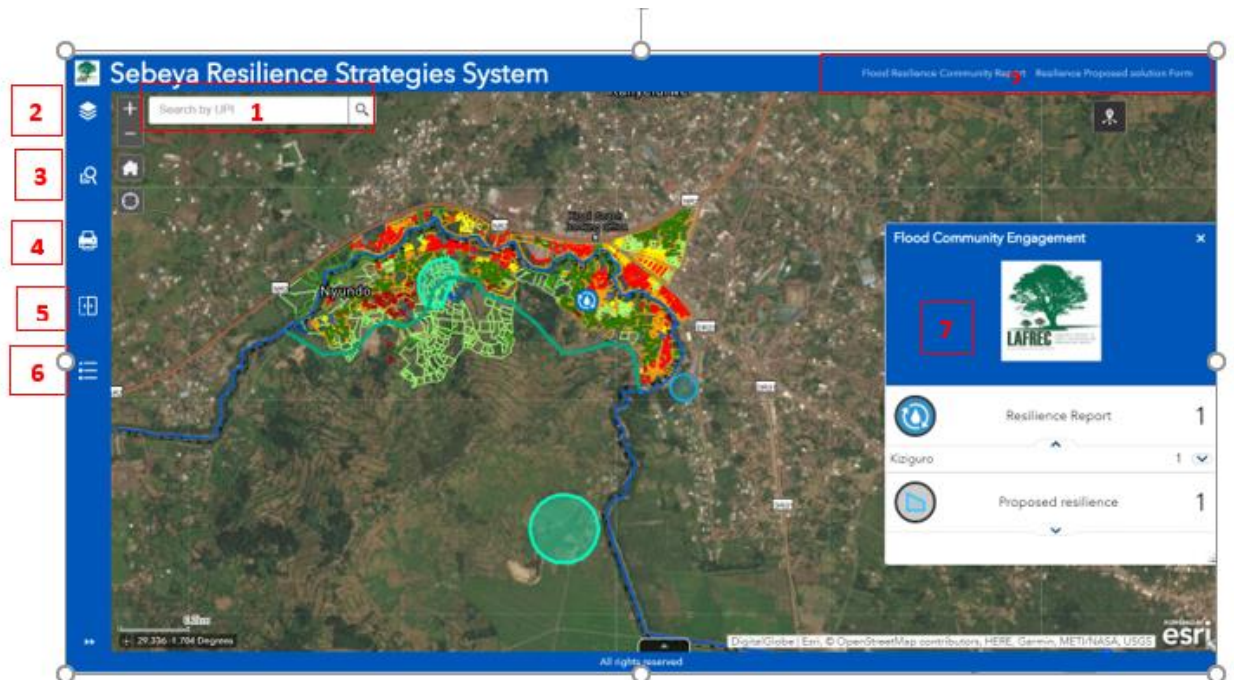


Figure 20: Sebeya Flood Resilience Strategies Digital Map

1. Search by UPI query,
2. Navigate to all layers,
3. Query for resilient buildings and Work done by stakeholder,
4. Print your map,
5. Compare different layers,
6. Map legend,
7. Summary of Community report, and

8. Flood resilience Reporting forms.

5.3. Relevance of the Application

Information is an open door to harness and assess resilience, engaging the community is the key to that door. The flood resilience Interactive Map is a flood resilience platform where anyone could contribute by informing others and give information on flood resilience in a real time. The FRDIM will serve both the community and stakeholders as a decision-making platform and rapporteur platform. This platform is needed to assess what have been put in place and assess them with time. The main contributor will be the flood lead resident in each cluster. Today Rwanda has initiated a project targeting poorest people in rural area to get a smartphone. It is time to teach the local population that they can use those phones by contributing and reporting real life event like flood. The all system of application will play a role of informant, archiving, reporting and decision-making system.

5.4. Use of the Application

During household survey, respondent highlighted the importance of the community to directly participate in flood resilience. The population perceives that people affected by flooding in Sebeya catchment should extremely be involved in building resilience. Indeed, in the household survey, 84% said that they would like to represent flood resilience activities as flood lead resident or focal person in terms of follow-up, 3.72% said that they would not like to take such role and 12,3% said that they have no idea, that it will depend on what it involves and what they will gain.

People have a strong will to participate in flood resilience as key agent through taking over different roles as: controlling people for removing rocks and sand on the river, follow-up resilience and implementation of resilience strategies, introduce flood evening “*Akagoroba k’umyuzure*” in English correspond to “evening reflecting on flood” to inform people and share experience, advocate for vulnerable population.

The lead agent for flood resilience report tool would be the key agent to report in prior flood resilience techniques in place. The lead agent will encourage the population to contribute and reporting the important information. It will be preferable to have one lead agent by cluster, this will help in the efficiency of the reporting tool. Data reported will be accessed in flood resilience system and will be verified and approved by LAFREC project.

CHAPTER VI: CONCLUSION AND RECOMMENDATIONS

6.1. Conclusion and Recommendations

In conclusion, popular techniques put in place to reduce flood risk are planting trees and put sand bags around doors or Sebeya rivers. People living around Sebeya are still claiming that it is not enough because even if the methods are the most affordable ones but they are not adequate to reduce flood risks. They would like to stay and live in their respective village because it is where they have their assets. However for them to stay there something should be done and they are ready to help for any technique which would help them to stay in their home area. Taking into account the group discussion and the resilience strategies, population of Sebeya still think that people can do more than what is already in place. From their point of view Sebeya need strong strategies as engineering mechanism like deviation of the river. Some people think that deviation of the river should cause problems to the environment and bring new surprises. There is a need to do further studies to reduce the risks Sebeya river is causing. Achieving resilience requires to put together financially actions oriented and opinion wise oriented. A new strategy put in place should supplement or to completely cover a gap produced by an existing one. Thus to make Sebeya River sustainably resilient there is a need to assess what is in place is a key. That why encouraging the community to use the FRDIM system developed is a way to achieve a flood resilient community. The Flood Resilience Digital Interactive Map tool will represents a transparent system to monitor work done by stakeholders on flood resilience and give them a voice and eye to the community for their contribution and assessment on flood resilience progress.

Methods in place have been reported most of them as not efficient, to improve the resilience. therefore, there is need to take into consideration flood resilience proposed, further studies must be done on flood engineering methods like river deviation and Artificial lakes. Afforestation which is one of the important method used for flood resilience, should be strategic by planting fruit trees instead of planting bamboo or *Eucalyptus*. The method can help at the same time in flood reduction and food scarcity protection. Some of the people living in Sebeya catchment have planted fruit trees and said that the fruit should be a next generation solution since not only they have problem of flood but also food.

With the current online target to reach everyone with a smartphone by 2020, by giving vulnerable community Made in Rwanda smartphone and other smartphone by whoever wants to contribute to the initiative, there is a need to think about how each village can have a flood

resilience lead agent with a smartphone in priority. The initiative could be undertaken by REMA through LAFREC project and feed the Sebeya community with smartphones.

6.2. Room for Further Research

This study was done to assess flood resilience in place. However the study don't go further in providing more details on the feasibility of each solution. Therefore there is a need for other research to assess the feasibility of artificial lake in terms of water infiltration, soil quality, reduction of peak flow, possibility of the reservoir to be well managed and not fill up and cause additional problems. Studies are also needed to run a model for a long term feasibility of the deviation of Sebeya river in terms of ecosystems conservation and possible future impact in terms of riparian population.

This study will contribute in guiding LAFREC on the work to do on Sebeya for flood resilience and guide for the early warning system by identifying houses where the mobile application could support for warning. The platform could help to well inform citizen about the upcoming risk per household.

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Appendices

Appendix 1. Survey Questionnaire

Label

This research is being undertaken in association with the LAFREC project to investigate and improve flood resilience among individuals, and communities who are at risk of flooding. The aim of the research is to gather valuable information to inform policies and procedures and to improve the emergency response of people living around Sebeya Catchment.

Questions

Household Identification

Household ID

Plot Number

Cell Name

Sector Name

Village

UPI

Number of people in your home

How long have you been in the area

Location

House Status

Flood Exposure

Do you live in flood area

Has your property ever been flooded

Flood damages and resilience

What has been the cause of flooding

Other Causes

What did you loses or have been damaged when flood took place

How many people died

What type of animals

Number of animal lost

Type of diseases

Other damages
Can you estimate in Rwf what you have lost
What action, if any, have you taken, to be ready to minimize the impact of flooding
Other Action
More explanation on action taken
Is there anything preventing you from taking action to minimize the impact of flooding
Other prevention
how important do you believe the involvement of your community is in responding to flooding
What are the main institutions or programs you know which involve in flood resilience strategies
Action takenby LAFREC
Action taken by MINEMA or Government
Action taken by Water for Growth or RWFA
Action Taken By Care International
Action taken by Red Cross
Action taken by District or Sector Office
Action taken by other
Do you think your community has the necessary information and/or resources to be ready for flooding
What additional information and/or resources do you feel your community needs?
Are there some government measures to reduce the level of flood risk?
If yes, can you cite them and show the most used?
What methods of warning your community would you suggest being appropriate and/or effective?
What more do you think your community could do to minimize the impact of flooding incidents on you and others within your community?
Is there a nominated 'lead resident' for issues such as flooding in your community?
Would you consider taking on such a role?
Any other comments
Picture of the residence
Picture of sandbags
Picture of Tree plantation
Picture of terraces

Picture of drainage system

Other resilience picture

Appendice 2. Propose solution Survey questionnaire Survey form

Survey123 for ArcGIS

My Survey

Name
Marie Aimee

Village
Kiziguro

Email
shutaine03@gmail.com

Telephone Number

Geo-Location

What is the proposed resilience for this Area

- ☐ Sand Bag
- ☐ Flood retaining wall
- ☒ Tree plantation
- ☐ Early warning system
- ☐ Artificial lake
- ☐ River deviation
- ☐ Other

Comment on proposed strategie

Planting additional Bamboo trees in this area

General Comment

Figure 21: Proposed resilience Form

Appendice 3. Flood event and Resilience Report Survey form

Survey123 for ArcGIS

X

My Survey



Name

Village

▼

Email

Geo-Location



form type

☐ Flood event report

☐ Damage report

☐ Resilience Faillure report

General Comment

✓

Figure 22: Overview of the form

Survey123 for ArcGIS

×

My Survey

form type

☒ Flood event report
☐ Damage report
☐ Resilience Faillure report

Flood Level Report

Flood level

^

☐ Major Flood
☐ Moderate Flood
☐ Minor Flood
☐ Action Flood

Estimate Depth in meter

Water duration in area

^

☐ 1-30 min
☐ 30-60 min
☐ 1 - 4 hours
☐ 4 - 6 hours
☐ 6 - 12 hours
☐ 12 - 24 hours
☐ 1 - 2 days
☐ 2 - 3 days

Flood Picture 1

Flood Picture 2

General Comment

Figure 23:Flood event report

Survey123 for ArcGIS

My Survey

Form type

☐ Flood event report

☒ Damage report

☐ Resilience Failure report

▼ Damages Report

What have been damaged

☐ Damaged building

☐ Damage road

☐ Loss of life

☐ Water and power supply

☐ Injuries

☐ Agriculture land

☐ Damaged house material

☐ Other damage

Extent of damages

☐ Very High level

☐ Moderate level

☐ Low level

☐ Insignificant level

Additional Comment

✓

Figure 24:Damage report form

Survey123 for ArcGIS

My Survey

☐ Flood event report

☐ Damage report

☒ Resilience Faillure report

▽ Resilience Problem report

What is the resilience reported

Resilience Technique Problems

☐ Destroyed

☐ Damaged

☐ Not working

☐ Removed

At which extend the method is destroyed

Additional Comment

Resilience Picture 1

Resilience Picture 2

Figure 25: Resilience problem report form